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WATER RESERVATIONS AND WATER AVAILABILITY IN THE YELLOWSTONE RIVER BASIN

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WATER RESERVATIONS AND WATER AVAILABILITY IN THE YELLOWSTONE RIVER BASIN

MAY 1982

by

Daniel A. Sobashinski and Diane Fitz Lozovoy

WATER MANAGEMENT BUREAU

WATER RESOURCES DIVISION

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

TABLE OF CONTENTS

Page

List of Tables v

List of Figures viii

Abstract ix

Introduction 1

Methods 8

Results 12

Appendix A: Detailed Description of DNRC Version of Yellowstone River Operations Study 25
Introduction 26
COMPUT Subroutine 29
Yellowstone River above Billings 29
Yellowstone River below Billings 33
TONGUE Subroutine 39
POWDER Subroutine 42
SUNDAY Subroutine 47

Appendix B: Input Data for Yellowstone River Operations Study 49
1975 Level of Development Flows 50
Reservations 50
Municipal Reservations 50
Irrigation Reservations 50
Instream Flow Reservations 77
Multiple Use/Storage Reservations . . . 77
Future Water for Wyoming 78
Reserved Indian Water Rights 78
U.S. Bureau of Reclamation Municipal and Industrial Water Use 78
Montana Water Rights Granted in the Yellowstone River Basin Since 1975 83
Utah International (Fence Creek) Project, Powder River Basin 83

Appendix C: Water Availability in the Yellowstone River Basin Under "Present" Conditions 87
Introduction 88
Methods 88
Results 92

Page

Appendix D: Water Available for Irrigation Reservations in the Yellowstone River Basin 105
Introduction 106
Methods 106
Results 107
Yellowstone River above Billings 107
Yellowstone River below Billings 113
Conclusions 114

Literature Cited 116

Acknowledgments 117

LIST OF TABLES

		Page
1.	Water Reservations in the Yellowstone River Basin	3
2.	Excess Flows: Yellowstone River at Livingston, Montana	13
3.	Excess Flows: Stillwater River at Absarokee, Montana.	14
4.	Excess Flows: Clarks Fork at Edgar, Montana	15
5.	Excess Flows: Yellowstone River at Billings, Montana.	16
6.	Excess Flows: Tongue River at Miles City, Montana	17
7.	Excess Flows: Yellowstone River at Miles City, Montana	18
8.	Excess Flows: Powder River at Locate, Montana	19
9.	Excess Flows: Bighorn River at St. Xavier, Montana	20
10.	Excess Flows: Yellowstone River at Sidney, Montana	21
A-1.	Boysen Reservoir: Operating Criteria	35
A-2.	Buffalo Bill Reservoir: Operating Criteria	36
A-3.	Yellowtail Reservoir: Operating Criteria	37
A-4.	Prairie Dog Creek and South Fork Tongue River Reservoirs: Specifications and Operating Criteria	40
A-5.	New Tongue River Reservoir: Specifications and Operating Criteria	41
A-6.	Hole-in-Wall and Crazywoman Creek Reservoirs: Specifications and Operating Criteria	43
A-7.	Clear Creek Reservoir: Specifications and Operating Criteria	44
A-8.	Fence Creek (Utah International) Reservoir: Specifications and Operating Criteria	45
A-9.	U.S. Bureau of Reclamation Offstream Storage Reservoirs: Specifications and Operating Criteria	48
B-1.	Yellowstone River at Livingston: 1975 Level of Development Flows	51
B-2.	Stillwater River near Absarokee: 1975 Level of Development Flows	52
B-3.	Clarks Fork at Edgar: 1975 Level of Development Flows	53
B-4.	Yellowstone River at Billings: 1975 Level of Development Flows	54
B-5.	Bighorn River near St. Xavier: 1975 Level of Development Flows	55
B-6.	Tongue River at Miles City: 1975 Level of Development Flows	56
B-7.	Yellowstone River near Miles City: 1975 Level of Development Flows	57
B-8.	Powder River at Arvada: 1975 Level of Development Flows	58

Page

B-9. Powder River near Locate: 1975 Level of Development Flows 59
B-10. Yellowstone River near Sidney: 1975 Level of Development Flows 60
B-11. Municipal Depletions: Yellowstone River 61
B-12. Irrigation Depletions: Yellowstone River above Livingston 62
B-13. Irrigation Depletions: Stillwater River at Absarokee 63
B-14. Irrigation Depletions: Clarks Fork at Edgar 64
B-15. Irrigation Depletions: Yellowstone River between Livingston and Billings 65
B-16. Irrigation Depletions: Tongue River above Miles City. 66
B-17. Irrigation Depletions: Bighorn River below St. Xavier 67
B-18. Irrigation Depletions: Yellowstone River between Billings and Miles City 68
B-19. Irrigation Depletions: Powder River above Locate . . 69
B-20. Irrigation Depletions: Yellowstone River between Miles City and Sidney 70
B-21. Monthly Distribution of Depletions from Irrigation Reservations 72
B-22. Monthly Distribution of Non-Irrigation Depletions . . 73
B-23. Instream Flow Reservations 74
B-24. Bighorn River Basin: Depletions for Wyoming under Level B Year 2000 Recommended Plan 79
B-25. Tongue River Basin: Depletions for Wyoming under Level B Year 2000 Recommended Plan 80
B-26. Powder River Basin: Depletions for Wyoming under Level B Year 2000 Recommended Plan 81
B-27. Reserved Indian Water 82
B-28. Montana Water Rights Granted in the Yellowstone River Basin Since 1975 84
B-29. Depletions from Powder River Basin for Utah International (Fence Creek) Project 85

C-1. Depletions Used in Yellowstone Opstudy Model for "Future" and "Present" Conditions 90
C-2. 1985 "Without Development" Level Flows: Bighorn River at St. Xavier, Montana 93
C-3. Present Conditions - Excess Flows: Yellowstone River at Livingston, Montana 94
C-4. Present Conditions - Excess Flows: Stillwater River at Absarokee, Montana 95
C-5. Present Conditions - Excess Flows: Clarks Fork at Edgar, Montana 96
C-6. Present Conditions - Excess Flows: Yellowstone River at Billings, Montana 97
C-7. Present Conditions - Excess Flows: Tongue River at Miles City, Montana 98

Page

C-8. Present Conditions - Excess Flows: Yellowstone River at Miles City, Montana 99
C-9. Present Conditions - Excess Flows: Powder River at Locate, Montana 100
C-10. Present Conditions - Excess Flows: Bighorn River at St. Xavier, Montana 101
C-11. Present Conditions - Excess Flows: Yellowstone River at Sidney, Montana 102

D-1. Yellowstone River at Livingston: Percent of Irrigation Reservations Satisfied 108
D-2. Stillwater River near Absarokee: Percent of Irrigation Reservations Satisfied 109
D-3. Clarks Fork of the Yellowstone River at Edgar: Percent of Irrigation Reservations Satisfied . . . 110
D-4. Yellowstone River from Livingston to Billings: Percent of Irrigation Reservations Satisfied . . . 111
D-5. Yellowstone River - All Irrigation Reservations above Billings: Percent of Irrigation Reservations Satisfied 112

LIST OF FIGURES

Page

1. Yellowstone River Basin 9

2. Yellowstone River Basin Model Nodes 10

A-1. Adjustment of Depletions at Livingston to Mitigate Instream Flow Shortage 31

A-2. Adjustment of Depletions at Livingston to Mitigate Instream Flow Shortage at Billings 32

ABSTRACT

In December 1978, the Montana Board of Natural Resources and Conservation issued an order on the reservation of water in the Yellowstone River Basin. This order, the first to establish water reservations on any river in Montana, reserved water for municipal use, irrigation, offstream storage, and instream flow. An annual total of 716,237 acre-feet was reserved for future consumption by irrigators and municipalities. The largest instream flow reservation was granted by the board for 5,578,890 acre-feet per year at Miles City. This study was designed to determine: (1) the amount of water currently available for appropriation, taking into account existing uses, water reservations, and estimated future depletions by Wyoming and Indian tribes; and (2) whether there will be enough water available to fully satisfy the irrigation reservations above and below Billings, Montana.

INTRODUCTION

In the years prior to 1974, a substantial number of applications for water use permits for drawing large amounts of water from the Yellowstone River were received by the Montana Department of Natural Resources and Conservation (DNRC). Many of these applications requested significant amounts of water for energy-related industrial development. Reacting to concerns that industrial water development would harm municipal, agricultural, and instream water use, the Montana Legislature passed the Water Moratorium Act of 1974, which suspended all applications for water use permits for diversions larger than 20 cubic feet per second (cfs) or storage over 14,000 acre-feet in the Yellowstone Basin until March 10, 1977. During this period, the state determined the amount of water available for allocation and quantified instream flow requirements for the Yellowstone River and its tributaries. The moratorium also allowed local, state, and federal agencies to assess their future water requirements and submit applications for the reservation of water.

The Water Use Act of 1973 made it possible for the State of Montana and the federal government to reserve water for existing or future consumptive uses, and to maintain a minimum flow level and quality of water. To reserve water, a qualified public body must apply to the Board of Natural Resources and Conservation and establish:

1. the purpose of the reservation
2. the need for the reservation
3. the amount of water necessary for the purpose of the reservation
4. that the reservation is in the public interest.

The board has the authority to modify the reservation if the objectives of the reservation are not met or if, in the case of reservations requiring diversion or storage, progress toward the completion of the necessary facilities is not being made. Such progress is to follow a development plan submitted by the user and approved by the board. The board may reallocate all or part of the instream flow reservation if it determines that the amount of water reserved is not required to serve its designated purpose and that the need for the reallocation has been shown by an applicant to outweigh the need of the original instream flow requirement.

The moratorium on new appropriations encouraged applicants to submit applications for reservations before November 1, 1976. Between 1973 and 1976, DNRC prepared an environmental impact statement that analyzed the effects the water reservations and increased water use would have on the basin's hydrology, geomorphology, water quality, wildlife, existing uses, recreation, and economics (DNRC 1976). The moratorium was extended for one year

in order to enable federal agencies to apply for offstream storage reservations and to allow DNRC enough time to gather and analyze the data necessary for decisions on the granting of reservations.

By November 1, 1976, 30 applications for water reservations were filed with DNRC for Yellowstone River water. A total of 1,181,559 acre-feet per year was requested for irrigation. This total included thirteen requests from conservation districts, two from irrigation districts, and three from the Montana Department of State Lands. Eight municipalities filed applications totaling 391,500 acre-feet per year for domestic and municipal use. Two reservations, for a total of 1,600,000 acre-feet per year for multipurpose reservoir storage, were filed on the Tongue and Powder rivers by DNRC. In addition, the U.S. Bureau of Reclamation filed for a reservation totaling 729,500 acre-feet per year for three offstream storage reservoirs on the Yellowstone River between Billings and Miles City.

Requests for major nonconsumptive reservations of instream flows, the maximum being 8,206,723 acre-feet per year at Sidney, were filed by the state's Department of Health and Environmental Sciences and Department of Fish, Wildlife and Parks. All of the applications filed by conservation districts mentioned instream flows, although only the North Custer Conservation District's application mentioned a specific figure.

Notices of these applications were printed in local papers and, in the summer of 1977, public hearings on the applications were held in Billings and Helena. Attorneys representing the applicants presented their cases for reserved water before the hearings examiner. At the end of the hearings process, the examiner requested that each applicant prepare a proposed order for the board.

The board used these proposed orders, transcripts of the hearings, and final discussions to make its decision. The board's findings, made in December 1978, are summarized in Table 1.

The board also established priorities for the use of this water. Municipal use has first priority. Upstream from the mouth of the Bighorn River, instream use has second priority and agriculture third. Below the confluence of the Bighorn River to the North Dakota border, agriculture has second priority and instream flow third. Storage reservations have the lowest priority.

Since the reservations were granted, the board has authorized two changes. The first, authorized in September 1980, increased the reservation for the City of Billings from 41,229 acre-feet per year, with an average diversionary flow rate of 56.9 cfs, to 53,500 acre-feet, with an average diversionary flow rate of 74.0 cfs.

TABLE 1

WATER RESERVATIONS IN THE YELLOWSTONE RIVER BASIN

MUNICIPAL RESERVATIONS

Town	Annual Reservation (acre-feet)
Livingston	4,510
Big Timber	365
Columbus	883
Laurel	7,151
Billings	41,229
Miles City	2,889
Glendive	3,281
Broadus	605
TOTAL	60,913

MULTIPURPOSE/STORAGE RESERVATIONS

Applicant	Reservoir	Annual Reservation (acre-feet)
DNRC	Tongue River	383,000
US Bureau of Reclamation	Cedar Ridge	121,800
	Buffalo Creek	68,000
	Sunday Creek	539,000
TOTAL		1,111,800

TABLE 1 (continued)

IRRIGATION RESERVATIONS

Applicant	Annual Reservation (acre-feet)	Maximum Diversion (cfs)
Park Co. Conservation District (CD)	64,125	445.9
Sweet Grass Co. CD	46,245	363.4
Stillwater Co. CD	16,755	122.1
Carbon Co. CD	22,676	130.7
Yellowstone Co. CD	57,963	378.2
Bighorn Co. CD	21,239	143.8
Treasure Co. CD	18,361	118.6
Rosebud Co. CD	94,147	540.7
North Custer Co. CD	39,375	---
Powder River Co. CD	13,680	---
Prairie Co. CD	68,467	552.7
Dawson Co. CD	45,855	330.8
Richland Co. CD	45,620	354.2
Little Beaver CD	12,773	---
Buffalo Rapids Project	11,997	16.55
Montana Dept. of State Lands (No. 9931-r)	14,679	86.11
Montana Dept. of State Lands (No. 9933-r)	25,889	185.2
Montana Dept. of State Lands (No. 9934-r)	15,078	---
US-BLM	2,924	12.287
US-BLM	17,476	75.76
TOTAL	655,324	

TABLE 1 (continued)

INSTREAM FLOW RESERVATIONS

Location	Annual Reservation (acre-feet)
Yellowstone River at Livingston	1,879,013
Shields River near Clyde Park	35,434
Shields River at Wilsall	21,764
Big Timber Creek	28,267
West Boulder River	74,853
East Boulder River at mouth	23,146
Boulder River at Contact	137,120
Boulder River at Big Timber	195,163
Stillwater River at mouth	379,795
Yellowstone River at Billings	3,679,968
Bighorn River at mouth	2,477,987
Yellowstone River at Miles City	5,578,892
Tongue River at Wyoming state line	244,799
Tongue River at mouth	54,289
Powder River at mouth	95,201
Yellowstone River at Sidney	5,429,310

The second change, authorized in November 1980, was a result of a decrease in the instream reservation of the Yellowstone River above the mouth of the Bighorn River (as measured at Billings) held by the Department of Fish, Wildlife and Parks and the Department of Health and Environmental Sciences. The original reservation was established on the basis of the 65th percentile flow, which means that flows in excess of this reservation could be expected in 65 out of 100 years. The change reduced this reservation from the 65th to approximately the 83rd percentile. This change increased the amount of water available for the irrigation reservations.

The reservations were made with the stipulation that all senior water rights must be met first. Currently, many of these senior rights have not been quantified, particularly the use rights which were established simply by putting the water to beneficial use. These rights are legally unrecorded, but are valid if the water user can prove the date on which the beneficial use began and the amount of water used. These rights, along with filed and decreed rights originating before July 1, 1973, are currently being adjudicated throughout the state, as part of a legislative mandate. When the adjudication process is complete and all senior rights in the Yellowstone Basin are quantified, the water available for the reservations may be slightly reduced.

Indian and federal reserved rights have yet to be quantified in the basin. These rights are also senior to the reservations and are currently being quantified through direct negotiations between the Reserved Water Rights Compact Commission, representing the State of Montana, and the Indian tribes in the state. The tribes, in asserting their rights as given in the Winters Doctrine, state that Indians have "prior rights to water resources which arise upon, border, traverse or underlie reservations in amounts necessary to satisfy present as well as future needs of the reservations." Since these rights have yet to be determined, they must be estimated on the Crow and Northern Cheyenne reservations in Montana and the Wind River Reservation in Wyoming. These estimated appropriations must then be accounted for when determining water availability in the Yellowstone River.

Wyoming's share of water in the Yellowstone Basin, as defined in the terms of the Yellowstone River Compact, also has not been quantified. The compact divides unused and unappropriated waters of the Yellowstone River's interstate tributaries (Clarks Fork of the Yellowstone River, Tongue River, Powder River, and Bighorn River) as of January 1, 1950, between Wyoming and Montana.

According to the compact, Wyoming and Montana are entitled to the following percentages of surplus flow after January 1, 1950:

	Percent of surplus flow allocated	
Tributary	Wyoming	Montana
Clarks Fork	60	40
Bighorn	80	20
Tongue	40	60
Powder	42	58

Surplus flow is determined on an annual water year basis measured from October 1 of any year through September 30 of the following year. The quantity of water to which the percentage factors (indicated above) shall be applied through a given date in any water year shall be, in acre-feet, equal to the algebraic sum of:

(1) the total diversion for irrigation, municipal, and industrial uses developed after January 1, 1950, and above the point of measurement during the period from October 1 to that given date;

(2) the net change in reservoir storage in all reservoirs above the point of measurement completed subsequent to January 1, 1950, during the period from October 1 to that given date;

(3) the net change in storage in existing reservoirs above the point of measurement, which is used for irrigation, municipal, and industrial purposes developed after January 1, 1950, during the period October 1 to that given date;

(4) the quantity of water that passed the point of measurement during the period from October 1 to that given date.

(In all cases, the point of measurement is located at the confluence of the interstate tributaries and the Yellowstone River.)

Supplemental water for holders of water rights prior to January 1, 1950, also is subtracted from the tributary flows to determine surplus flows. Supplemental water is defined as that quantity of unused and unappropriated water necessary to fully satisfy the water requirements of pre-1950 water rights in both states and, therefore, cannot be allocated between the states in the apportionment.

Wyoming has independently estimated its share of the surplus flow from the four tributaries. However, Montana does not necessarily agree with these estimates. It is obvious that some of the present flow in the tributaries specified in the compact may not be available to Montana in the future because Wyoming will someday appropriate its full share.

METHODS

In order to determine the amount of water available in excess of the reservations, the water reserved for consumptive or in-stream uses must be subtracted from the flow for a given level of development at the proper location, as if it had already been appropriated. The water available in excess of the reservations is not constant because of annual and seasonal variations in the flow of the Yellowstone River and its tributaries. Therefore, the water available in excess of the reservations varies from year to year as well as during the course of a year.

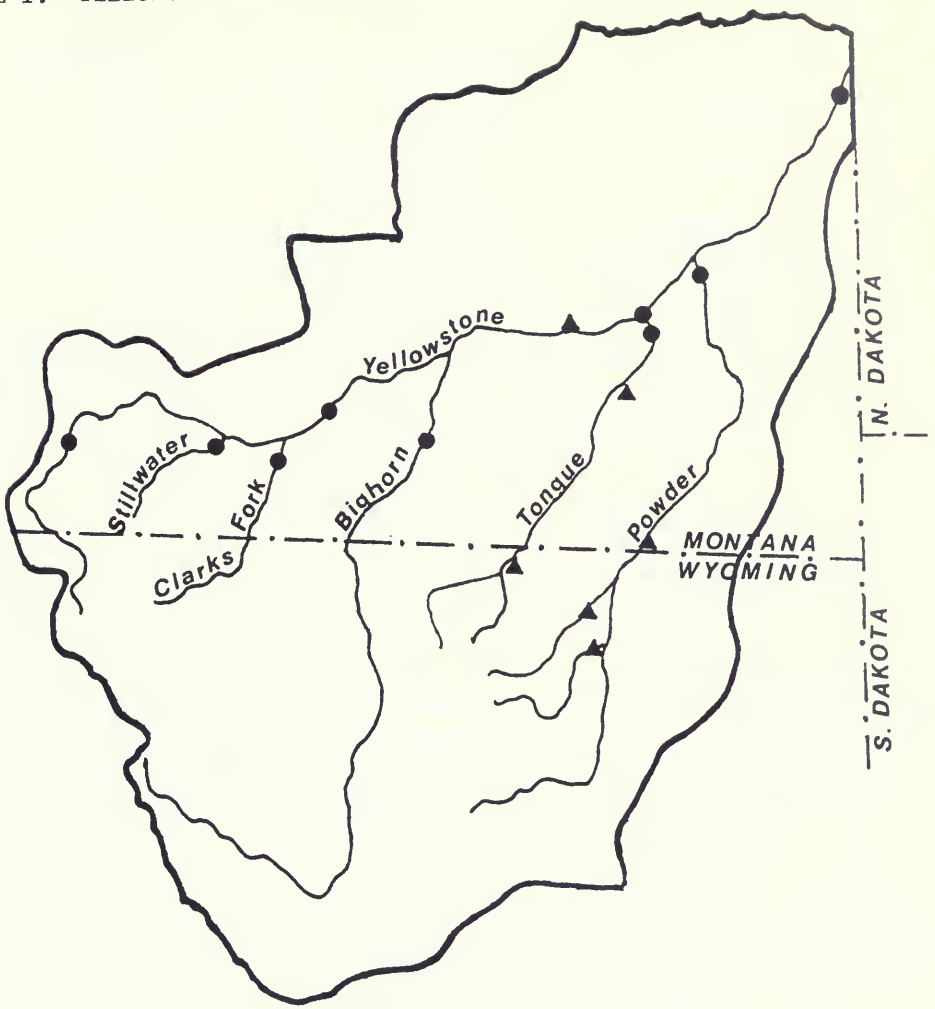
A computer model was used to determine the amount of water available for appropriation in the Yellowstone Basin. The amount of surplus water available for appropriation was determined by accounting for all reservations and estimating depletions for future Wyoming, Indian, and federal uses. Existing uses were accounted for by using the 1975 level of development flows, as determined by the U.S. Bureau of Reclamation, and subtracting the depletions for provisional water rights permits issued in Montana between 1975 and 1981.

The model was developed by the U.S. Bureau of Reclamation, Upper Missouri Region, in Billings, Montana, and is referred to as the Yellowstone Basin Operations Study Model (Opstudy) (USBOR 1978). Opstudy was modified by DNRC during the course of this study. Therefore, the output from the model represents the viewpoint of DNRC, not the U.S. Bureau of Reclamation.

Opstudy is an accounting model that performs a mass balance at predetermined nodes (gauging statons, reservoirs, or other points of interest) in the river system. Inputs to the system (such as inflows from upstream river reaches, tributary inflows, irrigation return flows, and reservoir releases) and losses (such as diversions and evaporation) are determined between nodes and are used to calculate the flow at a given node. In addition, when the calculated streamflow at a given node is less than a requested high priority reservation, the depletions from lower priority reservations are reduced to meet the higher priority reservation. For example, if instream flow reservations are not met in the Yellowstone River at Livingston, irrigation depletions would be reduced until the reserved amount is met.

The nodes of the Yellowstone River Opstudy model are shown in Figure 1. Figure 2 depicts the order by which calculations are

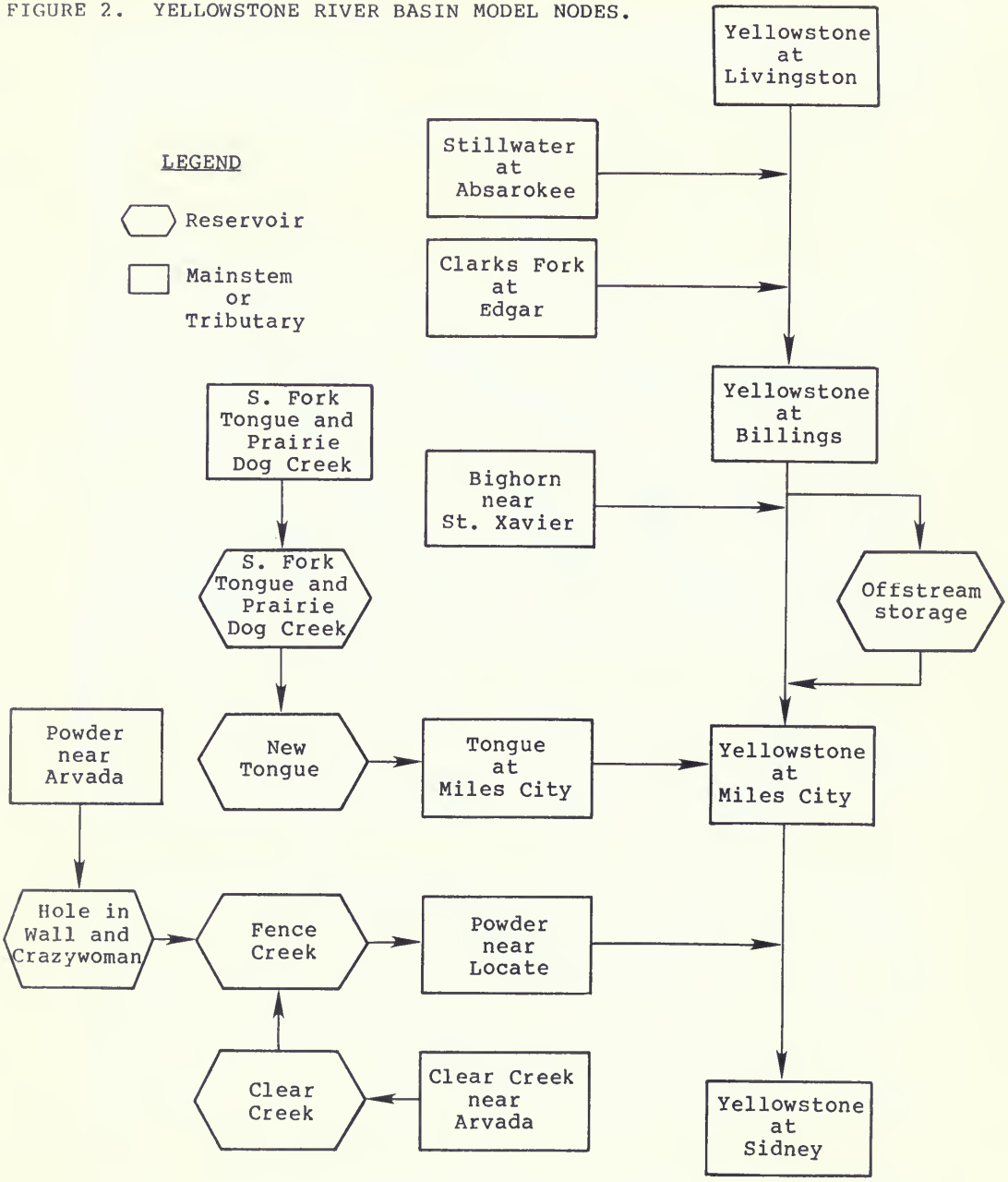
FIGURE 1. YELLOWSTONE RIVER BASIN.



● YELLOWSTONE MAINSTEM OR TRIBUTARY NODE

▲ RESERVOIR NODE

FIGURE 2. YELLOWSTONE RIVER BASIN MODEL NODES.



made at each node. The flows calculated for upstream nodes are used to determine flows for downstream nodes.

A more detailed description of the Opstudy computer model and its subroutines is presented in Appendix A. Four subroutines, each for a different portion of the Yellowstone River basin, are incorporated into the model. Furthermore, in Appendix A, the logic of each subroutine and the manner in which the subroutines are interrelated for determining water availability in the entire basin are described.

Opstudy computes monthly streamflows, adjusted for all inputs and internodal relationships, at each node. The most important source of input data for the nodes at gauging stations is the 1975 level of development flows. These flows are calculated by adjusting the historical flow of any given year before 1975 by the difference between the depletions that occurred in 1975 and the depletions that occurred during the year of interest. When this is done, the streamflows represent flows that would occur as though the depletions, diversions, and reservoir operations that existed in 1975 had been in operation throughout the entire period of record.

The 1975 level of development flows for the period 1939-1975 were used in the Yellowstone Opstudy model. These flows were obtained from the U.S. Bureau of Reclamation. The methods used to determine these flows are outlined in the report: Yellowstone River Basin and Adjacent Coal Fields: Depletion Study - 1975 Level of Development (USBOR 1976).

The Yellowstone Opstudy model does not compute streamflows in the Bighorn River Basin above St. Xavier, which is approximately 85 miles upstream from the confluence of the Bighorn and Yellowstone rivers and approximately 2.5 miles downstream from Yellowtail Dam. Streamflow data at St. Xavier were generated by the Bighorn River Opstudy model developed by the U.S. Bureau of Reclamation. These flows reflect the operation of Yellowtail Dam and include estimated depletions from the Wyoming portion of the Bighorn River Basin. Depletions for Wyoming were obtained from the Yellowstone Level B Year 2000 Recommended Development Plan in the Report on the Yellowstone Basin and Adjacent Coal Area, Volume 7: Wind-Bighorn-Clarks Fork (MRBC 1978a). These depletions represent development levels for the year 2000, as estimated by the Missouri River Basin States Association (formerly the Missouri River Basin Commission) in cooperation with state and federal agencies.

Opstudy calculates the monthly and annual excess flows at each gauging station represented by a node in the model. The excess flows represent the amount of water that would be available for consumptive use after all of the reservations and estimated future depletions have been taken into account. Future depletions include estimates for Wyoming from the Level B-2000

study as well as Indian and non-Indian federal reserved water rights. The storage reservations were filed by the U.S. Bureau of Reclamation and DNRC.

All of the input data required to run the model are described in Appendix B. The methods used to calculate depletions associated with the consumptive reservations and estimated future uses are also described.

The excess flows at a given node include the accumulated excess flows for all upstream nodes. For example, excess flows at Billings include the excess flows calculated for the Clarks Fork at Edgar, the Stillwater River near Absarokee, the Yellowstone at Livingston, and all excess flows available on the Yellowstone from Livingston to Billings.

During months when there is no excess flow at a given node, adjustments are made in the model so that a portion or all of the excess flows at upstream nodes are not available for appropriation because, if appropriated, they would only increase the shortage downstream. For example, when flows at Billings do not meet all of the reservations, excess flows at Livingston are decreased, even though the streamflow at that location may exceed all of the reservations. If the shortage at Billings is greater than the excess flow at Livingston, the excess flow at Livingston is set at zero. Otherwise, the excess Livingston flow is decreased by an amount equal to the shortage at Billings.

Because the 1975 level of development flows are used to generate the model output, the excess flows represent 37 years of data that reflect the effect of all reservations and future estimates of depletions on water availability over varying hydrologic conditions. From this, Opstudy calculates average excess flows and exceedance frequencies at the 80th, 60th, 40th and 20th percentile levels on a monthly and annual basis.

RESULTS

The excess flows calculated by the model are shown in Tables 2 through 10. One table is presented for each basin gauging station represented by a node in the model. The percentile flow levels are interpreted in the following manner: The 80th percentile flow for a given month indicates that, based on the 37-year period of generated data, the given flow will be equalled or exceeded eight out of ten years, on the average. For example, in Table 10, the excess flow in the Yellowstone River at Sidney during January is at least 50,100 acre-feet eight out of ten years, on the average.

Readers should note that the sum of the monthly frequency flows will not equal the annual frequency flows, since different data are used to calculate these flows.

TABLE 2

EXCESS FLOWS: YELLOWSTONE RIVER AT LIVINGSTON, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	1.9	0.0	0.0	0.0	0.0	4.3
February	3.0	0.0	0.0	0.0	0.0	5.0
March	2.4	0.0	0.0	0.0	0.0	3.3
April	5.0	0.0	0.0	0.0	0.0	0.0
May	96.8	0.0	0.0	19.3	90.4	225.1
June	224.7	0.0	6.2	107.8	192.4	526.5
July	203.9	0.0	0.0	184.3	247.2	388.3
August	47.3	0.0	0.0	0.0	12.0	114.0
September	18.5	0.0	0.0	2.7	7.3	36.7
October	5.2	0.0	0.0	0.0	0.0	3.0
November	6.3	0.0	0.0	0.0	0.0	12.0
December	3.5	0.0	0.0	0.0	0.0	7.1
Annual	618.4	6.2	264.6	544.3	727.8	1225.7

TABLE 3

EXCESS FLOWS: STILLWATER RIVER AT ABSAROKEE, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	3.9	0.0	0.5	4.1	5.5	7.5
February	3.7	0.0	1.8	3.7	4.1	7.1
March	4.1	0.0	0.7	2.9	4.2	6.8
April	8.6	0.0	0.0	0.0	11.2	15.8
May	35.0	0.0	0.0	21.2	49.1	77.6
June	78.8	0.0	6.2	84.1	111.4	149.5
July	77.5	0.0	0.0	86.8	103.1	139.3
August	17.2	0.0	0.0	0.0	12.0	42.5
September	7.5	0.0	0.0	1.5	7.3	13.6
October	7.2	0.0	0.0	2.9	9.2	14.6
November	7.9	0.0	5.4	10.9	12.0	13.4
December	5.4	0.0	5.4	6.2	7.5	9.1
Annual	256.7	22.5	206.1	241.0	329.8	414.7

TABLE 4

EXCESS FLOWS: CLARKS FORK AT EDGAR, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	6.1	0.0	0.5	6.9	8.8	12.7
February	6.3	0.0	4.5	7.1	8.4	10.4
March	6.3	0.0	2.2	5.9	8.2	10.3
April	6.3	0.0	0.0	0.0	2.2	10.6
May	29.5	0.0	0.0	21.2	28.5	67.0
June	53.8	0.0	0.0	26.5	54.3	133.2
July	43.3	0.0	0.0	19.2	35.7	83.5
August	10.6	0.0	0.0	0.0	0.0	25.6
September	6.9	0.0	0.0	0.0	3.3	13.8
October	9.4	0.0	0.0	6.9	10.6	15.4
November	8.2	0.0	5.4	10.0	10.8	16.2
December	8.3	0.0	9.3	10.2	11.2	12.9
Annual	195.0	33.2	134.4	165.6	204.0	347.6

TABLE 5

EXCESS FLOWS: YELLOWSTONE RIVER AT BILLINGS, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	14.4	0.0	0.5	10.7	12.9	30.7
February	26.2	0.0	4.8	14.3	22.1	51.7
March	22.0	0.0	2.2	5.9	17.8	38.2
April	39.8	0.0	0.0	0.0	17.2	71.9
May	129.7	0.0	0.0	21.2	101.8	288.4
June	281.9	0.0	6.2	118.4	380.4	666.3
July	330.9	0.0	0.0	196.0	373.5	596.1
August	55.9	0.0	0.0	0.0	12.0	114.0
September	27.5	0.0	0.0	2.7	7.3	50.7
October	38.8	0.0	0.0	6.9	34.6	77.5
November	25.6	0.0	5.4	13.7	27.3	49.3
December	18.8	0.0	10.0	17.5	24.1	33.5
Annual	1011.5	120.1	630.0	856.8	1137.8	1853.0

TABLE 6

EXCESS FLOWS: TONGUE RIVER AT MILES CITY, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	4.1	0.0	0.8	1.9	3.4	7.2
February	8.8	0.4	0.4	2.0	4.8	12.0
March	18.1	0.0	0.2	4.3	14.2	30.9
April	10.2	0.0	0.1	0.1	0.1	22.6
May	22.5	0.0	0.0	0.0	33.8	45.0
June	58.0	0.0	6.2	49.1	65.6	105.4
July	7.4	0.0	0.0	0.0	0.0	15.1
August	0.0	0.0	0.0	0.0	0.0	0.0
September	0.3	0.0	0.0	0.1	0.1	0.1
October	3.9	0.0	0.0	0.0	0.0	10.2
November	5.0	0.0	0.1	0.1	7.7	10.9
December	3.3	0.0	0.7	1.8	3.2	6.4
Annual	141.7	13.3	70.4	107.2	173.7	244.4

TABLE 7

EXCESS FLOWS: YELLOWSTONE RIVER AT MILES CITY, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	135.1	24.5	94.6	143.1	153.9	231.2
February	176.1	85.7	130.5	148.8	183.3	257.0
March	146.0	0.0	82.6	110.8	162.3	250.3
April	119.0	0.0	30.3	77.4	99.7	274.6
May	139.9	0.0	0.0	42.9	101.8	288.4
June	293.2	0.0	6.2	118.4	380.4	690.2
July	334.2	0.0	0.0	196.0	373.5	632.8
August	60.6	0.0	0.0	12.0	12.0	114.0
September	32.5	0.0	0.0	7.3	7.3	50.7
October	78.0	0.0	1.6	6.9	60.7	157.2
November	97.6	0.0	15.5	38.3	118.7	221.7
December	130.4	32.7	95.4	141.1	171.4	213.4
Annual	1742.6	343.1	1044.0	1671.4	2029.1	2747.8

TABLE 8

EXCESS FLOWS: POWDER RIVER AT LOCATE, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	8.6	0.2	6.4	9.8	10.4	14.6
February	25.4	0.1	8.2	11.6	15.1	33.1
March	53.1	0.0	7.6	24.2	40.8	99.1
April	17.3	0.0	0.0	0.2	12.6	31.6
May	12.3	0.0	0.0	0.0	0.0	25.6
June	53.4	0.0	0.6	25.7	59.8	88.5
July	15.2	0.0	0.0	1.3	13.8	29.9
August	4.0	0.0	0.0	1.0	1.0	1.0
September	5.4	0.0	0.0	0.6	0.6	14.5
October	14.4	0.0	0.3	8.8	17.0	25.7
November	10.1	0.0	8.4	11.7	13.8	18.9
December	7.4	0.2	6.8	8.3	8.7	10.4
Annual	226.7	59.7	167.5	198.5	245.6	366.9

TABLE 9

EXCESS FLOWS: BIGHORN RIVER AT ST. XAVIER, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	6.7	0.0	0.0	0.0	0.0	12.1
February	20.2	0.0	3.8	10.2	20.8	40.7
March	0.2	0.0	0.0	0.0	0.0	0.0
April	16.0	0.0	0.0	0.0	0.0	46.5
May	8.8	0.0	0.0	0.0	0.0	5.0
June	0.5	0.0	0.0	0.0	0.0	0.0
July	11.4	0.0	0.0	0.0	0.0	24.0
August	0.0	0.0	0.0	0.0	0.0	0.0
September	3.8	0.0	0.0	0.0	0.0	0.0
October	20.3	0.0	0.0	0.0	6.2	48.5
November	13.2	0.0	0.0	0.0	0.0	29.9
December	9.0	0.0	0.0	0.0	0.0	17.1
Annual	110.2	0.0	7.2	20.8	104.0	230.9

TABLE 10

EXCESS FLOWS: YELLOWSTONE RIVER AT SIDNEY, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	159.5	50.1	138.3	156.9	189.4	261.1
February	196.9	75.2	145.7	165.5	195.5	273.6
March	275.4	0.0	171.3	219.7	268.5	420.2
April	162.8	0.0	2.7	53.9	116.1	306.4
May	124.7	0.0	0.0	21.8	75.8	197.8
June	385.0	0.0	62.1	157.2	491.9	824.9
July	340.7	0.0	0.0	118.9	365.3	646.9
August	65.2	0.0	0.0	14.7	41.2	119.0
September	52.5	0.0	0.0	9.5	15.3	81.0
October	94.3	0.0	11.1	25.7	92.8	184.3
November	104.7	0.0	36.3	53.5	127.7	201.4
December	140.9	34.4	89.6	125.1	185.4	253.8
Annual	2102.5	476.7	1270.6	2055.5	2314.7	3526.8

Monthly frequency flows are calculated by ranking the excess flows for the different months from highest to lowest flows then determining the proper percentage of the ranked sample that falls within a given frequency. The member of the sample closest to the cutoff percentage represents the value listed in Tables 2 through 10 for the proper frequency.

The flows are ranked for each month following the procedure just described. The same procedure is used to rank the annual flows. Thus, there are thirteen separate, independent datasets analyzed. A given percentile annual flow does not represent the summation of the monthly flows for the same percentile, but is the result of a separate analysis conducted using only annual flows.

The monthly analyses indicate the amount of water available for appropriation directly from the river, particularly for irrigation. Assuming that a reliable supply of irrigation water is needed in at least eight out of ten years, the tables show that there is not a reliable supply of that amount of water anywhere in the Yellowstone mainstem; the 80th percentile flows are all 0.0 for the irrigation months. The majority of the 60th percentile flows are also 0.0 during the irrigation season because of the relatively large instream flow requirements.

The annual frequency flows indicate that water is available throughout the basin on a yearly basis. This water would be available for offstream storage projects and could be used for irrigation or industrial purposes, depending on the costs associated with the storage.

All of the excess flow calculations are affected by the values estimated for future Wyoming depletions and Indian reserved water rights. The excess flows also reflect the assumption that all of the reservations are final. As previously mentioned, the Board of Natural Resources and Conservation has the authority to modify each reservation if the objectives of the reservation are not met or progress towards the completion of necessary facilities is not made. Therefore, the excess flows in Tables 2 through 10 should be viewed as the amount of water available for appropriation, considering all of these assumptions. The values should be used only to obtain general information on water availability and the seasonal availability of water in the basin.

Because all of the consumptive reservations of Yellowstone River Basin water have yet to be developed, and because Indian reserved water rights and the amounts of water apportioned to Wyoming under the Yellowstone River Compact have yet to be quantified or developed, some additional water in excess of the flows presented in Tables 2 through 10 is now available for use. This water would be available on a provisional basis until the reservations, Indian reserved water rights, and Wyoming's share of the water under the terms of the Yellowstone River Compact have been quantified, developed, and put to beneficial use.

Water availability in excess of the flows described in Tables 2 through 10 is calculated in Appendix C. The depletions used to calculate provisional water availability also are explained in that appendix.

The values in Tables 2 through 10 indicate that little or no water for direct withdrawal for irrigation is available in the basin. Therefore, the logical alternative for obtaining irrigation water would seem to be through the irrigation reservations of the Conservation Districts (CDs) in the basin. However, all of the water reserved by the CDs may not be available during a given year. This is particularly true above Billings, where the irrigation reservations are junior to the instream flow reservations. Future depletions in the Wyoming portion of the Yellowstone Basin and by the Northern Cheyenne and Crow Indians may also have a minor effect on the amount of water available for the irrigation reservations below Billings. The availability of water for the irrigation reservations is analyzed in Appendix D. Results indicate that shortages would occur if the irrigation reservations in the portion of the basin above Billings were fully developed. Below Billings, where the irrigation reservations are senior to the instream flow reservations, no significant shortages are expected.

APPENDIX A

DETAILED DESCRIPTION OF DNRC VERSION OF YELLOWSTONE RIVER OPERATIONS STUDY

INTRODUCTION

The computer model consists of four subroutines designed to calculate water availability at the locations shown in Figure 1. The subroutine names and the portions of the basin to which they apply are:

COMPUT - Yellowstone River mainstem from above Livingston to Sidney, including the Stillwater River, the Clarks Fork of the Yellowstone River, and the Bighorn River below St. Xavier.
TONGUE - Tongue River Basin and its tributaries in Wyoming and Montana.
POWDER - Powder River Basin and its tributaries in Wyoming and Montana.
SUNDAY - Proposed Yellowstone River offstream storage reservoirs between Billings and Miles City.

The streamflows calculated in the TONGUE and POWDER subroutines are used to determine streamflows for the COMPUT subroutine. Water available as inflow to the SUNDAY subroutine is calculated in the COMPUT subroutine; releases in excess of the demands are input at a downstream location in the COMPUT subroutine. Streamflows in the Bighorn River downstream to St. Xavier were computed in the U.S. Bureau of Reclamation's Bighorn River Opstudy model. Therefore, these flows were external input to the Yellowstone model. Depletions below St. Xavier and the resultant streamflows at the mouth of the Bighorn River were calculated in the COMPUT subroutine of Yellowstone Opstudy Model.

In order to determine water availability with the Yellowstone Opstudy model, the following types of data were required:

1. 1975 level of development flows
2. Expected future depletions
3. Reservoir operating criteria
4. Instream flow reservations
5. Municipal, irrigation, and multipurpose storage reservations
6. Water rights granted in Montana since 1975.

All of the categories above, except reservoir operating criteria, are presented and explained in Appendix B. Reservoir operating criteria are explained in this appendix.

The model operates on a monthly time step and generates output for the same interval. A mass balance is performed on each node, which accounts for gains and losses in a given month. The following parameters can contribute to a gain at any given node:

1. Calculated inflows from upstream nodes
2. Section gain (Inflows from node of interest to next upstream node. These are 1975 level of development flows and include inflows from all tributaries in the channel reach.)
3. Irrigation return flows
4. Reservoir releases
5. Reservoir spills.

Return flows from municipal, industrial, and energy related uses are subtracted from diversions external to the model. Therefore, when determining water availability, Opstudy only accounts for the depletions associated with these uses. For this reason, return flows are not considered to be gains at any given node.

Possible losses that can occur at any given node are:

1. Irrigation depletions
2. Energy development depletions
3. Industrial depletions
4. Livestock depletions
5. Non-energy mineral-related depletions
6. Reservoir inflow
7. Reservoir evaporation.

For the purpose of this report and in the framework of the model, a diversion is defined as the total withdrawal at a given location from a surface water supply. A portion of this total withdrawal returns to the surface water supply from either diversion loss return flows, or return flows from the point of use. Depletions are defined as the fraction of the diversion that is lost to the source of supply. These losses are due to consumptive factors, such as evaporation, plant transpiration, or deep percolation.

Depletions from the Yellowstone mainstem accounted for in the model were simply subtracted from the streamflow at the proper node. Diversions from the mainstem were not directly accounted for; they were handled indirectly because they were never subtracted from the streamflow. The underlying assumption with using this method is that the diversion losses would return to the mainstem in a relatively short amount of time and need not be subtracted from the streamflow. Also, the diversion losses would actually accrue throughout a stream reach defined by two nodes. However, because of the nodal structure of Opstudy, the diversion losses (gains to the mainstem) can only be accounted for at the end of each reach. If diversions, rather than depletions, were subtracted from the mainstem streamflow, shortages that do not actually exist could be calculated.

Water would be diverted to fill and operate the U.S Bureau of Reclamation's three proposed offstream storage reservoirs between Billings and Miles City, as well as Utah International Inc.'s

Fence Creek Project on the Powder River near the Wyoming-Montana border. Thus, releases from these reservoirs are accounted for in the model on the basis of diversions rather than depletions. Diversion losses are accounted for because releases from the reservoirs are added to the flow at Miles City and depletions are subtracted. The difference between these two terms represents the diversion loss, or addition to the mainstem streamflow.

The predicted water uses for Wyoming in the Tongue River and Powder River basins (Level B Year 2000 study) are handled as depletions in the model. They are not accounted for as diversions for two reasons:

1. The predicted withdrawals are not separated into categories defining withdrawals from the mainstem of the Tongue and Powder rivers and withdrawals from proposed reservoirs in these basins.

2. The Level B Year 2000 Study has suggested that reservoirs be built to accommodate these predicted withdrawals (these are the reservoirs operated in the TONGUE and POWDER subroutines). However, the reservoirs, particularly those on the Powder River, are not designed to supply all of the withdrawals predicted in the study.

Many smaller reservoirs exist or are proposed to handle the withdrawals needed to supply the irrigation reservations in Montana. Because of the small size of these impoundments, they are handled as "run of the river" systems in the model. Withdrawals from these projects are handled as depletions, in the same manner as depletions are modeled on the Yellowstone mainstem.

In addition to performing mass balances at each node, the model checks the calculated streamflow with the instream flow requirements for the node. Depending on the priority of the instream flow reservation at the node, the model may readjust specific losses (such as irrigation depletions) in order to increase the streamflow and meet the instream flow requirement.

The four subroutines in the DNRC Yellowstone Basin Opstudy model are discussed separately in the following pages.

COMPUT SUBROUTINE

The COMPUT subroutine calculates streamflows and determines water availability on the Yellowstone mainstem from Livingston to Sidney. It also calculates water availability and streamflows at the mouths of the Stillwater River and the Clarks Fork of the Yellowstone River. Outflows generated from the TONGUE, POWDER and SUNDAY subroutines are used as inputs to the COMPUT subroutine and are added to the streamflows in the Yellowstone mainstem at the proper location. Streamflows from the Bighorn River above St. Xavier, computed by the U.S Bureau of Reclamation's Bighorn River Operations Study model, also are used as input to the COMPUT subroutine.

Inflows from tributaries to the Yellowstone River (other than the Tongue, Powder and Bighorn rivers) are accounted for in "section gains." Section gains are defined as the increase in streamflows (1975 level of development flows) from one node to the next downstream node. Because these flows were developed from historical flows at gauging stations on the Yellowstone mainstem, they account for all tributaries contributing to the flow between the gauging stations. For example, the inflows from the Shields River, the Boulder River, Sweet Grass Creek, and all smaller tributaries are accounted for in the section gain on the Yellowstone River from Livingston to Billings.

Reservations and water rights granted since 1975 that pertain to depletions from the tributaries to the Yellowstone are handled in a similar manner. The input to the model aggregates all depletions (according to use) that occur between nodes. Therefore, no distinctions are made regarding the location of the depletions within the node. All depletions, from both the mainstem and the tributaries, are subtracted from the streamflow at the node.

Yellowstone River above Billings

Above Billings, where instream flow reservations have a higher priority than irrigation reservations, the streamflows are calculated as follows:

1. Subtract depletions from the 1975 level of development flow

2. Compare the computed flow with the instream flow requirement

3. If the computed flow is less than the instream flow requirement, decrease irrigation depletions so that the computed flow equals the instream flow requirement

4. If the difference between the computed flow and the instream flow requirement is greater than the irrigation depletion, the irrigation depletion is set at zero; the water shortage is then the difference between the instream flow requirement and the computed flow.

This procedure is used to calculate streamflows for the following nodes in the COMPUT subroutine:

- Yellowstone River at Livingston
- Stillwater River at Absarokee
- Clarks Fork of the Yellowstone River at Edgar.

Figure A-1 is a flow chart depicting the above procedure. The node for the Yellowstone River at Livingston is used in this example.

Streamflows at Billings are calculated by subtracting all of the depletions in the node from the 1975 level of development flows. However, if an instream flow shortage exists at Billings, the following procedure is used to readjust irrigation depletions:

1. The irrigation depletions from Livingston to Billings (including the Stillwater River and Clarks Fork of the Yellowstone River) are totalled.

2. The percentage of total irrigation depletion attributable to each node is determined.

3. The irrigation depletions are decreased at each node, according to the percentages developed in the above step, to meet the instream flow requirement at Billings.

A hypothetical case may help to explain these procedures.

Suppose, for example, that the instream flow shortage at Billings was 10 acre-feet in July and the irrigation depletions for that month were 8 acre-feet for the Billings node, 6 acre-feet for the Clarks Fork, 4 acre-feet for the Stillwater, and 2 acre-feet above Livingston.

The total depletion would be 20 acre-feet and the depletion percentage attributable to each station would be:

Billings	40%
Clarks Fork	30%
Stillwater	20%
Livingston	10%

The irrigation depletions at each station would then be decreased by 4, 3, 2 and 1 acre-feet, respectively.

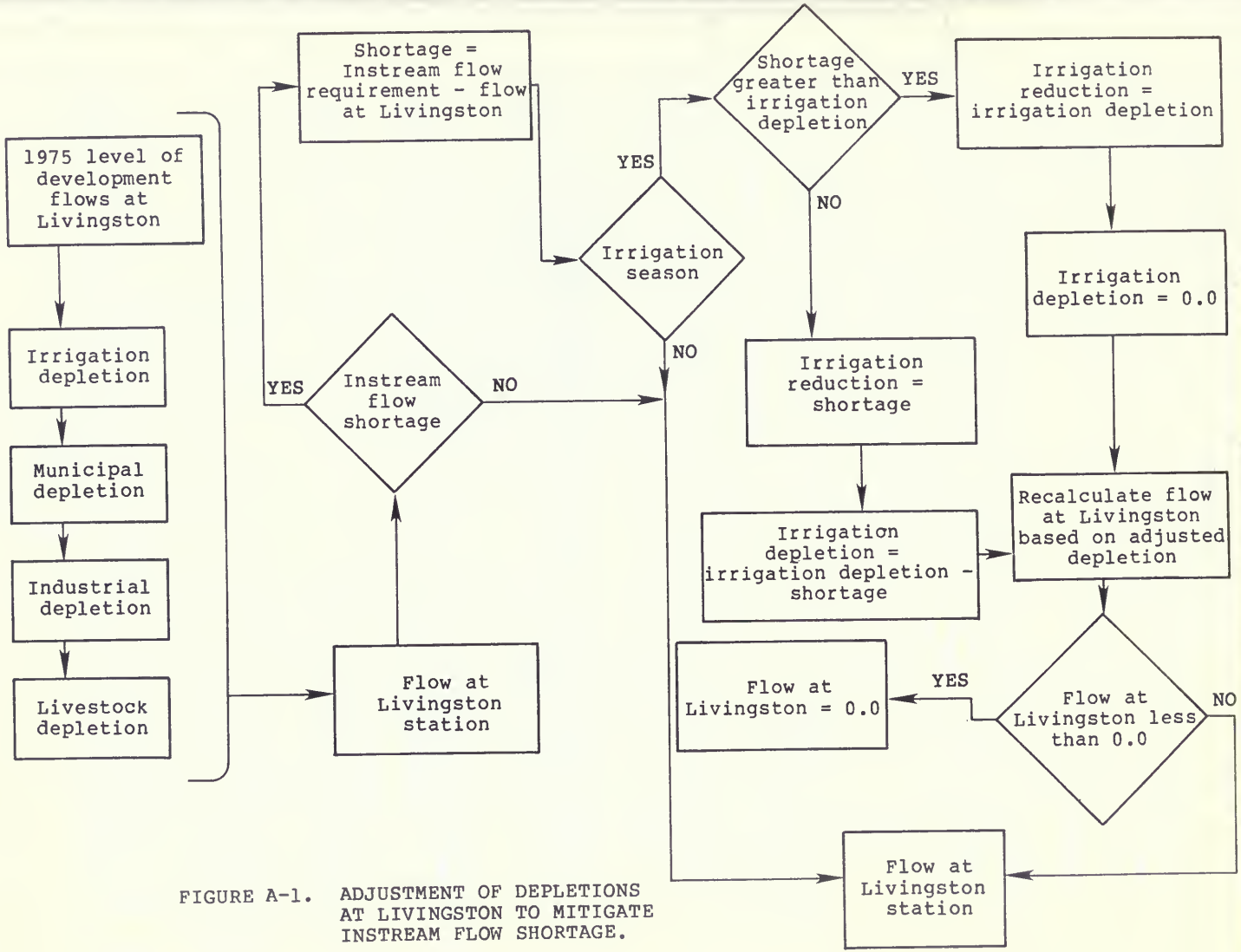
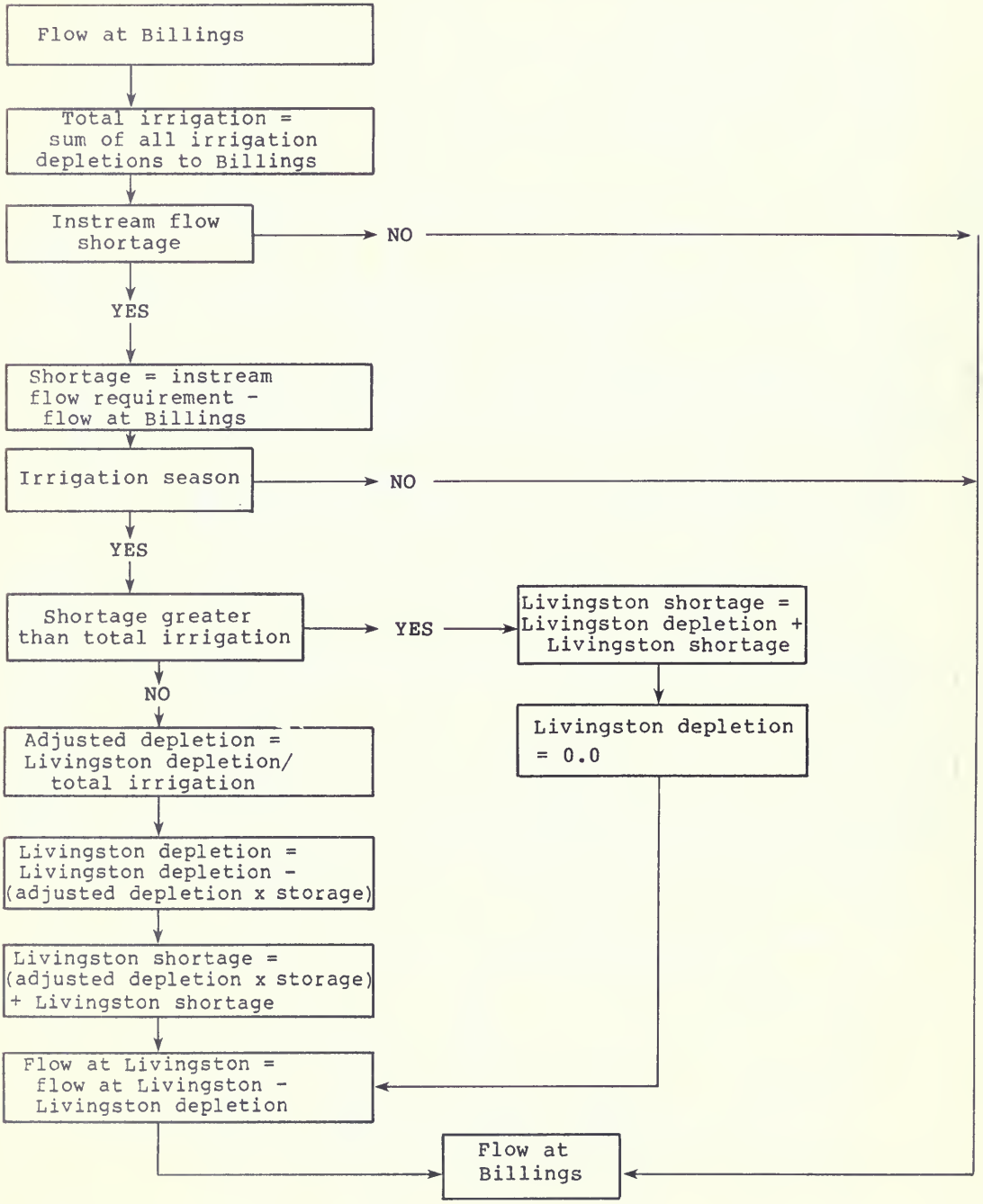


FIGURE A-1. ADJUSTMENT OF DEPLETIONS AT LIVINGSTON TO MITIGATE INSTREAM FLOW SHORTAGE.

FIGURE A-2. ADJUSTMENT OF DEPLETIONS AT LIVINGSTON TO MITIGATE INSTREAM FLOW SHORTAGE AT BILLINGS.



Additionally, if decreases in irrigation depletions had been previously computed at upstream stations, the decreases associated with the instream flow shortage at Billings would be added to the previously calculated decreases. The flow chart in Figure A-2 illustrates the manner in which irrigation depletions at Livingston are adjusted to compensate for instream flow shortages at Billings.

If instream flow shortages still exist at Billings after all of the adjustments to irrigation depletions have been made, the excess flows at Billings and all upstream nodes are considered to be zero, even though water in excess of the instream flow requirement at the upstream nodes may have been previously calculated. This is due to the accounting nature of the Opstudy model. It is assumed that removing a unit of water at an upstream location would decrease the potential flow at the next downstream station by one unit. Therefore, even if excess water were available at the upstream nodes, its removal would increase the instream flow shortage at Billings.

Yellowstone River below Billings

The reservation priorities below Billings give irrigation a higher priority than instream flow requirements. Therefore, when computed streamflows on the mainstem below Billings (at Miles City and Sidney) are less than instream flow reservations, irrigation depletions from the mainstem are not adjusted.

Below Billings, offstream storage reservations have a lower priority than instream flow requirements. When instream flow shortages exist, no water is available for inflow to the proposed offstream storage reservoirs. This is discussed in greater detail in the section pertaining to the SUNDAY subroutine.

Because instream flow requirements have a lower priority than irrigation reservations, in some cases the calculated streamflows at Miles City or Sidney may be negative. When this occurs, depletions are decreased so that the streamflow equals zero.

The following uses, in the order in which they are listed, receive priority when depletions are decreased to adjust the flow to zero:

1. Irrigation
2. Industry
3. Energy
4. Livestock
5. Municipal.

For example, if the flow is calculated as -5 acre-feet and the irrigation depletion for that month is 6 acre-feet, the irrigation depletion would be decreased to 1 acre-foot. If the irrigation depletion were less than 5 acre-feet, the depletion

for industry would then be decreased in order to eliminate the negative streamflow calculation.

Flows at the mouth of the Tongue and Powder rivers are calculated in the TONGUE and POWDER subroutines.

Streamflows on the Bighorn River downstream to St. Xavier were calculated by the U.S. Bureau of Reclamation through its Bighorn River Opstudy Model. Depletions from the Bighorn River, Wind River, and Shoshone River in Wyoming, estimated in the Missouri River Basin States Association Level B Year 2000 study, were:

Irrigation	237,600 acre-feet/year
Municipal	3,058 acre-feet/year
Livestock	6,034 acre-feet/year
Industrial	9,660 acre-feet/year.

Two reservoirs in the Wyoming portion of the Bighorn River Basin were accounted for in the model. Boysen Reservoir, on the Wind River, and Buffalo Bill Reservoir, on the Shoshone River, were accounted for using the present operating criteria. The operating criteria for the reservoirs are presented in Tables A-1 and A-2. In addition, Yellowtail Reservoir on the Bighorn River in Montana also was taken into account. The operating criteria for the Yellowtail Reservoir are presented in Table A-3.

Depletions from Boysen Reservoir used in the Bighorn River model included the sale of 57,400 acre-feet of water per year. Depletions from the Yellowtail Reservoir included the sale of 300,000 acre-feet per year. The U.S. Bureau of Reclamation has the right to sell this water for municipal and industrial use.

The Bureau of Reclamation's Bighorn River Opstudy model uses all of the above information and 1975 level of development flows on the Wind, Shoshone, and Bighorn rivers to calculate the streamflow in the Bighorn River at St. Xavier. If instream flow shortages exist at this location, the irrigation depletions are not adjusted because the irrigation water rights are senior to the instream flow reservations. Storage rights in Yellowtail Reservoir also are senior to instream flow reservations.

Depletions below St. Xavier to the mouth of the Bighorn, the most significant being 136,400 acre-feet per year for irrigation on the Crow Indian Reservation, were accounted for with the depletions totalled at the Miles City node on the Yellowstone mainstem. Tributary inflows below St. Xavier, including the Little Bighorn River, were accounted for by the section gain on the Yellowstone mainstem from Billings to Miles City.

Excess flows on the Yellowstone mainstem below Billings are calculated by subtracting the calculated flow from the instream flow requirement. If the calculated difference is negative, the

TABLE A-1

BOYSEN RESERVOIR: OPERATING CRITERIA

October-January:	Set a uniform release rate to reach 580,000 acre-feet storage at end of January.
February:	Duplicate release during January.
March-July:	Assume 100% of runoff forecast on March 1. Make uniform releases to fill reservoirs (802,000 acre-feet) by end of July. Maximum release for March should not exceed 135,000 acre-feet.
August-September:	Release inflow but not less than 72,000 acre-feet in August and 71,400 acre-feet in September.

TABLE A-2

BUFFALO BILL RESERVOIR: OPERATING CRITERIA

October-January:	Set a uniform release rate to reach a storage of 200,000 acre-feet by the end of January.
February-June:	Assume 100% of runoff forecast on February 1. Make releases to fill reservoir (423,900 acre-feet) at end of June, but do not spill. Do not draw storage below 169,000 acre-feet until after April 1.
July-September:	After reservoir is full and spilling has ended, release irrigation requirements only.
Restrictions:	Release at dam should never be less than 50 cubic feet per second. Release to Heart Mountain power plant must always exceed 200 cubic feet per second.

TABLE A-3

YELLOWTAIL RESERVOIR: OPERATING CRITERIA

January-March:	Set a uniform release rate to reach a storage of 805,000 acre-feet by the end of March.
April-June:	Assume 90% of runoff forecast on April 1. Make uniform releases to fill reservoir (1,116,000 acre-feet) at end of June.
July:	If possible, make releases to draw storage down to 1,068,000 acre-feet.
August-December:	Release inflows or release enough water to draw the storage down to 980,000 acre-feet in December.
Restrictions:	Minimum flow during nonirrigation season is 1,000 cubic feet per second. Minimum flow during irrigation season is 14,000 cubic feet per second, plus 400-500 cubic feet per second for Bureau of Indian Affairs irrigation canal.

excess flow is assumed to be zero. Excess flows greater than zero represent the amount of water available for future use at each location. Because continuity of mass is assumed in the logic of Opstudy, when excess flows do not exist at a downstream station, all upstream stations are assumed to have excess flows of zero.

TONGUE SUBROUTINE

The TONGUE subroutine included the operation of two reservoirs in Wyoming and one in Montana. The Wyoming reservoirs do not currently exist, but were accounted for in the model in order to handle the Wyoming depletions as estimated in the Missouri River Basin States Association's Level B Year 2000 Recommended Development Plan. The Level B Plan included annual depletions of 15,920 acre-feet for irrigation, 30,311 acre-feet for energy, and 1,200 acre-feet for livestock use.

The Wyoming reservoirs designed to store and release water for these depletions (as suggested in the Level B Year 2000 plan) were the Prairie Dog Creek Reservoir and the South Fork of the Tongue River Reservoir. These reservoirs are combined and accounted for as one unit in the model. Inflows to the unit are estimated by totalling the 1975 level of development flows for Prairie Dog Creek and the South Fork of the Tongue River. The combined reservoir specifications and reservoir operating criteria are shown in Table A-4.

Release and spills from the Wyoming reservoirs are used as inflows to the New Tongue Reservoir in Montana. The New Tongue Reservoir represents the proposed expansion of the existing Tongue River Reservoir. Currently, the reservoir's storage capacity is 68,000 acre-feet. The most probable capacity for the expanded reservoir is 130,000 acre-feet, which is the storage capacity used in the TONGUE subroutine. Montana depletions from the New Tongue Reservoir (including reservations and water rights permits granted since 1975) and from the river downstream of the reservoir totalled 23,047 acre-feet for irrigation, 39,100 acre-feet for energy, 278 acre-feet for municipal uses, and 290 acre-feet for livestock use. The energy depletion represents the predicted future use of water by the Northern Cheyenne Indian tribe.

The specifications and operating criteria for the New Tongue Reservoir are shown in Table A-5. If the instream flow requirements at the mouth of the Tongue River could not be met by the releases from the New Tongue Reservoir (see Table A-5), the depletions below the reservoir were decreased. Irrigation depletions were decreased initially; if these decreases did not result in a calculated streamflow equal to the instream flow requirement, the energy depletions were decreased. If instream flow shortages still existed, there were no further adjustments to other depletions. The calculated flows at the mouth of the Tongue River (at Miles City) were then added to the flows for the node on the Yellowstone mainstem at Miles City.

TABLE A-4

PRAIRIE DOG CREEK AND SOUTH FORK TONGUE RIVER RESERVOIRS:
SPECIFICATIONS AND OPERATING CRITERIA

Specifications:	Capacity - 47,000 acre-feet Dead Storage - 11,300 acre-feet
Operating Criteria:	October-February: Release demand or inflow, whichever is greater. March-September: Release demands only.
Constraints:	If section gain on Tongue River from Wyoming-Montana border to mouth of Tongue River at Miles City (developed from 1975 level of development flows) is negative, increase release to adjust section gain to 0.0, but do not increase release by an amount greater than the inflow. If possible, release additional water to meet minimum end of month storages for New Tongue Reservoir. Do not increase release by an amount greater than the inflow.

TABLE A-5

NEW TONGUE RIVER RESERVOIR:
SPECIFICATIONS AND OPERATING CRITERIA

Specifications: Capacity - 130,000 acre-feet
Dead Storage - 1,400 acre-feet

Minimum end-of-month storages (acre-feet):

January	- 80,000
February	- 80,000
March	- 92,000
April	- 100,000
May	- 100,000
June	- 108,000
July	- 100,000
August	- 85,000
September	- 77,000
October	- 77,000
November	- 80,000
December	- 80,000

Operating Criteria: October-February: Release demands or inflow, whichever is greater.

March-September: Release demands. Release water to maintain instream flow requirement of 4,600 acre-feet per month, if necessary (subject to minimum end of month storages).

POWDER SUBROUTINE

The POWDER subroutine accounts for the operation of four reservoirs in the Wyoming portion of the Yellowstone River Basin. Three of the reservoirs, not yet constructed, were used to provide storage for the estimated depletions for Wyoming. These depletions, from the Missouri River Basin States Association's Level B Year 2000 Recommended Development Plan, totalled 10,900 acre-feet per year for irrigation and 42,220 acre-feet per year for energy.

The three reservoirs are Hole-in-Wall, Crazywoman, and Clear Creek. Hole-in-Wall and Crazywoman were considered as one unit in the model; the 1975 level of development flows for the Powder River at Arvada are used as inflow. Inflows to Clear Creek Reservoir were represented by the 1975 level of development flows for Clear Creek near Arvada. Operating criteria and specifications for these reservoirs can be found in Tables A-6 and A-7. Releases in excess of downstream demands were made, if possible, from these reservoirs in order to maintain flow in the channels and provide inflow for the downstream reservoirs.

Fence Creek Reservoir, near the Wyoming-Montana state line, was the fourth reservoir accounted for in the model. Fence Creek is an offstream storage site which has not yet been constructed. Water stored in Fence Creek will be used by Utah International Inc. for energy development in Montana.

Diversions from the Fence Creek Reservoir totalled 40,180 acre-feet per year, as specified in Utah International's Montana water right application. This total included 30,000 acre-feet for energy development, 7,610 acre-feet for agriculture, and 2,570 acre-feet for municipal uses. The Fence Creek Reservoir was operated to reflect on these diversion needs.

Depletions from these diversions were estimated as 30,000 acre-feet for energy, 950 acre-feet for municipal uses, and 3,805 acre-feet for irrigation. Powder River water will be diverted into four pipelines, each with a capacity of 100 cubic feet per second, and pumped to the Fence Creek Reservoir. A pipeline with a discharge capacity of 100 cubic feet per second will be constructed to convey water to the point of use in Montana.

Inflows to the Fence Creek project were calculated by adding the releases from the three upstream reservoirs in the model. The maximum diversion from the Powder River was restricted by the diversion and pumping capacity to the pipelines. Also, the logic of the POWDER subroutine was designed so that only water in excess of instream flow requirements could be diverted for storage in the Fence Creek Reservoir. The criteria used to determine the amount of water available for diversion, along with the reservoir specifications, can be found in Table A-8.

TABLE A-6

HOLE-IN-WALL AND CRAZYWOMAN CREEK RESERVOIRS:
SPECIFICATIONS AND OPERATING CRITERIA

Specifications:	Capacity - 54,000 acre-feet Dead Storage - 9,600 acre-feet	
Operating Criteria:	October-February:	Release demands or inflow, whichever is greater.
	March-September:	Release demands plus 50 cubic feet per second to maintain flow in the channel.

TABLE A-7

CLEAR CREEK RESERVOIR:
SPECIFICATIONS AND OPERATING CRITERIA

Specifications:	Capacity - 261,000 acre-feet Dead Storage - 30,000 acre-feet	
Operating Criteria:	October-February:	Release demands or inflow, whichever is greater.
	March-September:	Release 175 cubic feet per second for demands and to maintain flow in channel.
Constraints:	If section gain on Powder River from Wyoming to mouth (developed from 1975 level of development flows) is negative, increase October-February release to adjust section gain to 0.0, but do not increase release by an amount greater than the inflow. If the reservoir storage drops below 100,000 acre-feet during the March-September period, release only the amount required to meet the demands.	

TABLE A-8

FENCE CREEK (UTAH INTERNATIONAL) RESERVOIR:
SPECIFICATIONS AND OPERATING CRITERIA

Specifications:

Capacity - 106,700 acre-feet
Dead Storage - 14,300 acre-feet
Intake Diversion Capacity - 24,000 acre-feet per month (400 cfs)
Pipeline Release Capacity - 6,000 acre-feet per month (100 cfs)

Operating Criteria: Release demands through pipeline.

Constraints: If section gain on Powder River from Wyoming to mouth minus Montana depletions not related to the Fence Creek Project is less than instream flow requirements, decrease intake diversion as follows:

Intake diversion = Instream flow requirements - shortage

If shortage is greater than instream flow requirement, intake diversion equals 0.0.

In the model, depletions from the Powder River in Montana (representing reservations and permits granted since 1975) totalled 19,430 acre-feet for irrigation, 225 acre-feet for municipal uses, and 721 acre-feet for livestock use. If the instream flow requirement for the mouth of the Powder River at Locate could not be met by decreasing the amount of water diverted to the Fence Creek project, the irrigation depletions in Montana were decreased. Flows calculated at the mouth of the Powder River were added to the flows of the Yellowstone River at the Sidney node.

SUNDAY SUBROUTINE

The SUNDAY subroutine accounts for the operation of the three offstream storage reservoirs proposed by the U.S. Bureau of Reclamation. Water in excess of the instream flow requirement at Miles City is diverted from the Yellowstone mainstem between Billings and Miles City.

The three reservoirs--Sunday Creek, Buffalo Creek, and Cedar Ridge--were accounted for as one unit in the model. The individual and combined specifications of these reservoirs, along with their operating criteria, are presented in Table A-9. Once water in excess of the instream flow requirement was diverted and stored in the reservoirs, it was used for irrigation. Therefore, even though an instream flow shortage may have existed during a given month at Miles City, the model was not operated to release storage water in the reservoir for the purpose of eliminating the shortage.

Currently, the U.S. Bureau of Reclamation estimates a firm annual yield (for irrigation) of 230,000 acre-feet per year from the three reservoirs. The yields for each reservoir are: 175,000 acre-feet from Sunday Creek, 20,000 acre-feet for Buffalo Creek and 35,000 acre-feet for Cedar Ridge. These values represent diversions and were used in the model to calculate reservoir releases and storages. Depletions from the reservoirs were estimated from the depletion-diversion ratio in Table B-21 (see page) for the Yellowstone mainstem between Billings and Miles City. Based on this ratio of 0.70, the depletions for Sunday Creek, Buffalo Creek, and Cedar Ridge were 122,500 acre-feet, 19,000 acre-feet, and 24,000 acre-feet, respectively.

The reservoir inflows were subtracted from the streamflow at Miles City. Releases from the reservoirs were added to the flow at Miles City, while depletions were subtracted. The difference between these two represents the diversion loss, which was added to the flow at Miles City.

TABLE A-9

U.S. BUREAU OF RECLAMATION OFFSTREAM STORAGE RESERVOIRS: SPECIFICATIONS AND OPERATING CRITERIA

Specifications:

	Sunday Creek	Buffalo Creek	Cedar Ridge	Total
Capacity (acre-feet)	539,000	68,700	121,800	729,500
Dead Storage (acre-feet)	14,000	4,000	5,000	23,000
Pump Capacity (acre-feet per month)	59,500	10,000	15,000	84,500

Operating Criteria:

May-September: Release irrigation demands.
April-October: Store inflow from diversion up to reservoir capacity.

Constraints: No inflow from September to March. From April to October, store water in excess of instream flow requirement at Miles City, subject to pump capacity and storage capacity.

APPENDIX B

INPUT DATA FOR YELLOWSTONE RIVER OPERATIONS STUDY

1975 LEVEL OF DEVELOPMENT FLOWS

The flow base for the operations study is the 1975 level of development flows. These flows are defined as the river flow that can be expected if the depletion levels that occurred in 1975 existed for the period of record. Depletions are defined as the water beneficially consumed by municipalities, industries, irrigation, and livestock.

The 1975 level of development flows for the following stations are presented in Tables B-1 through B-10:

Yellowstone River near Livingston - USGS Station 6-1925
Stillwater River near Absarokee - USGS Station 6-2050
Clarks Fork at Edgar - USGS Station 6-2085
Yellowstone River at Billings - USGS Station 6-2145
Bighorn River near St. Xavier - USGS Station 6-2870
Tongue River at Miles City - USGS Station 6-3085
Yellowstone River at Miles City - USGS Station 6-3090
Powder River at Arvada - USGS Station 6-3170
Powder River near Locate - USGS Station 6-3265
Yellowstone River near Sidney - USGS Station 6-3295

RESERVATIONS

Opstudy subtracts the amount of water requested for each reservation (municipal, industrial, irrigation, instream flow, etc.) from the 1975 level of development flows as if that water had been used for its prescribed purpose. Tables B-11 through B-23 show the reservations as they were totalled according to gauging station for input to the Opstudy Model. Tables B-21 and B-22 show the distribution schemes used to develop monthly depletions for all of the consumptive reservations in the model.

Municipal Reservations

Municipal reservations are listed in Table B-11. In order to reflect the proper impact of a diversion from the river on water availability, return flows and the distribution of depletions throughout the year had to be determined. The return flows to the river were assumed to be 63 percent of the diversion (Mitchell 1982). The assumed distributions of the municipal depletions throughout the year are listed in Table B-22.

Irrigation Reservations

Irrigation reservations were granted to several conservation districts and irrigation districts, the Montana Department of State Lands, and the U.S. Bureau of Land Management. Tables B-12 through B-20 list the irrigated acres, diversions, and depletions granted to the different entities according to model location.

TABLE B-1

YELLOWSTONE RIVER AT LIVINGSTON: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						UNITS - 1000AF							
1938	102.81	84.57	74.74	58.54	50.21	77.09	110.51	351.81	852.66	470.50	226.69	139.99	2600.13
1939	129.51	102.96	83.62	81.79	67.63	87.30	150.41	541.61	499.56	319.30	163.89	107.99	2335.58
1940	102.21	75.58	65.99	56.21	54.87	70.68	94.05	457.41	578.26	250.80	121.09	93.49	2020.65
1941	95.50	77.50	71.66	67.45	61.12	67.69	73.54	329.81	430.26	237.70	157.69	164.09	1834.02
1942	171.51	130.56	109.75	86.66	75.72	80.32	157.61	317.41	698.76	474.90	191.19	118.79	2613.21
1943	99.73	88.10	78.52	69.43	61.84	83.10	199.81	428.21	1103.46	824.80	316.89	174.69	3528.59
1944	128.51	101.66	84.77	73.96	68.28	71.40	78.34	296.81	593.86	386.90	176.09	123.79	2184.38
1945	114.31	93.67	73.33	64.93	52.63	65.16	72.15	258.31	666.96	588.30	271.19	172.89	2493.84
1946	147.21	117.66	92.51	87.84	73.84	88.97	200.61	398.11	637.46	331.40	168.39	119.19	2463.20
1947	114.31	96.92	84.25	65.47	62.28	77.29	96.69	541.61	795.26	551.60	272.89	176.09	2934.67
1948	150.11	115.46	97.52	83.36	77.53	79.73	99.52	543.51	1023.46	432.10	226.39	132.79	3061.49
1949	111.11	92.94	72.75	59.04	56.13	68.85	149.41	578.01	741.56	393.20	199.89	130.99	2653.85
1950	125.01	99.46	72.45	55.33	54.51	56.85	93.02	262.31	879.56	701.30	287.69	180.29	2867.79
1951	164.71	136.06	115.25	84.67	70.10	82.92	123.51	517.61	710.06	582.70	331.79	185.59	3110.98
1952	149.41	113.46	86.71	72.45	68.72	76.14	171.41	630.41	837.66	407.60	218.99	128.69	2961.66
1953	101.00	78.24	71.36	72.98	62.89	69.69	83.14	198.51	737.56	461.80	195.39	120.89	2253.46
1954	100.94	87.94	72.77	60.47	55.67	60.09	92.64	496.11	682.06	562.70	235.09	141.09	2647.58
1955	104.11	88.61	75.05	68.32	56.86	71.16	78.02	237.01	609.06	359.60	195.19	119.19	2062.19
1956	108.11	93.09	85.33	85.30	76.36	85.58	130.21	566.41	1098.46	512.30	226.39	132.79	3200.34
1957	114.51	95.04	79.79	66.18	61.78	78.78	78.44	418.01	897.96	496.70	223.49	139.99	2750.68
1958	117.91	95.17	82.21	66.40	60.73	75.70	80.09	473.61	547.56	256.50	153.69	101.19	2110.77
1959	81.89	83.45	80.05	63.27	48.38	61.87	86.08	234.01	957.06	475.20	199.89	128.09	2499.25
1960	129.61	101.06	90.46	79.49	71.40	91.29	114.41	265.31	631.26	251.10	148.49	98.99	2072.88
1961	94.23	86.92	75.13	65.23	60.64	68.92	70.19	261.11	619.16	224.50	126.29	120.59	1872.92
1962	140.31	119.16	93.28	83.54	85.98	91.33	175.71	508.91	908.16	544.60	258.09	148.39	3157.47
1963	124.01	107.66	95.82	65.63	79.69	77.70	83.12	417.81	859.06	419.60	193.59	136.49	2660.19
1964	114.21	99.12	82.84	65.04	55.58	55.50	84.69	364.11	877.66	636.10	259.59	152.29	2846.74
1965	117.21	101.36	90.26	85.80	73.84	81.22	116.91	361.71	1162.16	790.60	329.19	203.49	3513.76
1966	174.61	128.76	101.25	81.49	66.34	80.84	106.61	420.01	532.06	288.20	153.59	114.19	2247.96
1967	103.41	86.60	77.31	74.51	71.72	82.11	84.61	371.51	1124.16	785.20	279.89	155.29	3296.33
1968	141.51	113.26	92.52	79.93	81.97	92.62	96.21	280.31	1041.16	612.70	322.69	224.29	3179.18
1969	182.91	135.16	106.05	87.60	91.67	97.98	165.51	675.71	707.16	495.00	219.39	131.09	3095.24
1970	123.01	103.26	89.41	79.99	75.07	82.78	81.51	411.41	1091.06	606.60	246.79	176.99	3167.89
1971	146.91	116.86	101.55	90.34	91.05	96.59	110.11	484.41	1215.06	811.90	320.19	195.19	3780.17
1972	162.09	128.67	98.56	87.72	81.53	103.28	117.09	425.83	1187.45	566.14	265.71	202.93	3426.98
1973	191.57	139.88	109.81	99.94	86.04	90.34	87.97	356.84	668.73	353.78	188.73	136.77	2510.38
1974	126.34	112.08	92.51	73.30	67.99	82.33	133.14	379.76	1340.22	743.31	298.55	162.81	3612.36
1975	137.12	103.69	87.22	69.31	63.54	82.79	84.24	205.58	821.40	920.75	314.37	181.55	3071.56
AVG	127.46	103.47	86.69	74.18	68.11	78.79	110.82	401.76	825.38	503.37	228.55	146.68	2755.27

TABLE B-2

STILLWATER RIVER NEAR ABSAROKEE: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						UNITS - 1000AF							
1936	18.11	13.87	11.89	8.96	5.85	9.80	17.49	76.63	112.20	35.81	29.98	21.55	362.13
1937	16.73	14.13	11.59	7.29	11.23	18.78	13.32	85.59	210.30	105.14	28.37	16.68	539.14
1938	22.07	15.65	15.04	12.59	13.24	13.71	18.19	73.61	207.10	127.14	39.06	24.29	581.68
1939	25.39	25.80	19.73	19.64	11.71	17.04	20.15	96.92	91.72	60.82	26.15	15.77	430.83
1940	18.10	14.98	12.13	13.23	12.25	11.06	18.21	101.72	204.50	71.30	25.44	24.60	527.51
1941	27.45	18.59	16.09	18.73	11.31	13.17	16.92	86.95	169.40	89.99	52.70	64.82	586.11
1942	52.69	30.25	25.23	25.51	15.22	15.68	30.81	102.22	209.00	201.34	50.68	30.26	788.88
1943	32.39	25.86	22.61	19.62	18.51	28.62	70.63	109.22	289.80	271.64	82.09	52.34	1023.32
1944	35.38	25.80	20.91	13.62	10.15	15.91	18.41	105.22	280.70	220.54	60.95	45.16	852.74
1945	33.29	25.77	20.90	18.27	15.09	18.16	23.14	60.78	211.80	225.54	74.09	43.13	769.95
1946	30.71	25.35	19.87	18.95	15.41	19.64	29.70	60.55	172.60	116.14	39.82	32.77	581.50
1947	31.93	23.97	20.53	19.55	15.20	25.12	34.52	125.82	185.70	192.64	62.48	44.38	781.83
1948	43.05	27.50	21.67	17.24	17.66	21.16	26.59	119.72	274.40	131.34	65.44	28.46	794.22
1949	25.94	21.98	18.77	15.24	10.42	16.12	28.03	113.52	172.00	97.12	37.85	33.10	590.08
1950	29.37	22.02	16.55	11.22	13.76	16.78	20.16	51.94	207.70	187.94	63.06	45.50	685.99
1951	38.37	30.02	23.34	20.76	18.39	19.91	26.02	95.75	137.90	179.24	84.64	38.68	713.01
1952	34.67	25.44	19.00	16.20	14.26	17.55	40.55	138.22	225.20	135.34	71.75	35.23	773.40
1953	24.97	22.31	19.44	17.60	15.09	15.33	19.80	46.14	180.20	136.94	55.73	28.71	582.25
1954	21.36	20.70	18.22	13.81	15.70	18.08	20.15	97.72	125.60	156.94	44.48	23.85	576.60
1955	26.16	22.72	16.02	12.86	12.04	12.71	21.86	47.34	149.00	97.44	36.51	21.82	476.49
1956	23.09	18.49	18.98	17.64	14.46	22.15	26.31	140.52	233.10	106.94	53.26	28.14	703.07
1957	24.03	22.15	22.91	13.36	12.20	14.26	19.50	139.82	342.40	227.24	58.21	41.00	937.09
1958	32.96	28.87	24.14	19.92	16.50	16.31	19.57	147.02	171.30	85.92	51.37	32.57	646.44
1959	25.57	24.29	22.67	18.58	15.15	19.44	24.30	56.79	266.80	128.74	43.79	26.58	672.69
1960	32.02	28.05	21.88	18.16	13.12	13.55	13.45	39.53	148.70	56.67	32.80	18.49	436.41
1961	21.62	19.87	17.76	15.11	14.30	12.65	8.68	55.57	149.10	46.68	27.80	45.02	434.15
1962	41.61	32.48	26.59	20.74	22.37	19.07	33.60	74.99	236.30	152.74	71.30	45.74	777.52
1963	37.69	25.01	20.97	18.35	19.90	14.97	20.37	100.02	266.00	119.54	43.65	41.07	727.53
1964	29.64	23.87	17.89	16.37	14.97	14.51	17.93	69.62	202.60	175.54	42.45	23.45	648.83
1965	20.78	23.39	22.93	20.39	18.55	16.39	25.15	58.19	245.10	205.24	78.13	48.49	782.72
1966	39.12	25.59	21.32	18.49	16.56	18.24	27.50	104.82	137.80	88.69	43.17	29.52	570.81
1967	31.47	22.45	19.01	19.63	15.20	20.98	15.81	73.16	325.20	272.34	63.61	41.16	920.05
1968	47.66	29.53	19.33	19.79	19.20	27.01	21.11	53.89	250.40	169.04	87.20	53.53	797.68
1969	39.81	25.56	21.12	19.92	18.35	18.41	25.57	96.96	172.50	160.24	50.65	25.87	674.95
1970	26.65	23.89	18.42	14.32	14.49	13.43	18.62	120.42	332.90	159.64	50.40	52.55	845.72
1971	35.69	26.15	22.72	22.93	21.56	17.86	27.75	94.72	282.10	187.54	70.98	63.82	873.81
1972	44.99	31.79	22.97	18.89	25.86	34.02	25.05	85.04	238.48	127.53	88.63	63.71	806.95
1973	43.83	29.32	22.91	17.61	16.37	18.23	39.15	113.07	207.66	131.02	47.51	54.23	740.89
1974	33.35	24.94	21.18	20.11	16.04	20.00	28.91	63.62	342.73	226.01	75.03	42.86	914.77
1975	33.27	26.38	17.58	16.06	11.77	18.37	36.32	118.22	271.61	391.50	86.29	35.35	1062.73
AVG	31.33	24.12	19.82	17.18	15.23	17.85	24.73	90.04	215.99	151.48	54.94	37.10	699.81

TABLE B-3

CLARKS FORK AT EDGAR: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						UNITS - 1000AF							
1929	25.34	24.19	16.22	13.55	13.97	20.37	19.76	94.24	208.36	139.01	29.88	25.83	630.71
1930	25.94	21.89	19.22	15.45	16.77	24.67	44.36	87.44	154.26	84.21	61.58	29.03	584.81
1931	56.64	28.69	25.72	25.05	17.87	15.97	21.56	86.84	166.26	14.91	14.98	18.13	492.61
1932	30.54	22.19	20.52	15.45	14.47	20.37	25.36	132.74	250.36	118.01	20.98	18.73	689.71
1933	24.14	25.39	21.82	19.95	15.17	26.77	17.66	59.24	324.36	50.31	19.08	31.53	635.41
1934	30.58	27.27	22.34	18.50	18.06	22.19	51.78	184.24	153.26	40.27	16.56	16.48	601.52
1935	25.99	26.09	23.50	21.44	18.46	18.99	26.91	70.29	281.26	155.91	25.28	21.23	715.34
1936	18.64	18.97	17.78	18.03	15.03	20.41	47.13	195.34	248.06	51.52	43.62	26.77	721.29
1937	31.88	30.21	14.17	13.44	16.43	23.01	21.72	143.44	210.66	80.50	10.68	13.50	609.63
1938	27.40	21.15	22.54	23.04	22.63	17.59	27.91	101.94	297.46	121.81	24.94	23.57	731.97
1939	29.23	33.68	25.92	23.47	16.02	26.19	35.82	161.74	162.76	86.10	19.78	14.04	634.74
1940	22.33	20.36	17.78	13.66	17.25	19.66	26.44	143.74	186.16	40.69	3.83	17.92	529.81
1941	34.36	25.99	25.96	20.52	16.92	16.56	22.44	118.64	168.56	57.77	38.09	81.95	627.75
1942	62.06	38.14	29.97	23.36	18.23	23.21	42.16	97.49	192.76	138.11	21.38	22.49	709.35
1943	30.71	32.15	30.26	23.28	22.38	34.11	83.13	125.94	324.06	288.51	77.77	44.41	1116.70
1944	32.39	32.41	26.98	22.17	20.10	20.09	19.78	102.14	236.66	142.11	27.24	33.97	716.03
1945	30.41	27.74	23.40	23.28	18.77	22.65	20.85	73.05	241.36	221.21	63.68	34.54	800.93
1946	35.41	33.27	26.95	28.32	21.35	24.69	56.61	93.94	209.86	106.01	26.09	25.73	688.22
1947	33.15	29.93	26.65	20.23	20.17	32.75	28.55	165.34	198.16	147.41	43.04	24.20	769.57
1948	35.35	32.16	27.52	23.95	26.97	24.67	25.98	155.74	294.76	82.99	29.52	19.24	778.88
1949	22.41	24.45	20.94	17.23	16.58	27.69	36.28	160.24	236.56	89.49	17.86	26.51	696.23
1950	33.60	29.57	29.36	23.10	21.17	23.08	28.06	69.25	268.76	232.51	61.24	45.99	865.68
1951	55.12	43.90	36.46	29.11	28.59	30.67	34.03	161.84	201.06	222.01	92.34	42.01	977.13
1952	45.61	37.20	26.08	28.16	27.68	24.99	50.00	148.44	234.26	95.21	48.86	22.73	789.21
1953	22.96	25.89	28.87	28.55	19.49	20.42	25.22	51.02	245.66	135.41	38.03	19.52	661.03
1954	18.74	27.79	27.73	24.78	22.95	22.27	28.90	165.54	181.36	175.11	32.29	22.12	749.57
1955	24.16	25.10	26.65	25.91	22.70	25.00	27.28	65.77	194.96	86.19	20.83	12.98	557.52
1956	18.36	26.56	28.51	21.57	22.07	31.83	38.49	181.24	345.96	122.61	44.95	26.46	908.60
1957	21.73	32.08	25.84	21.25	27.07	25.31	24.62	152.54	347.76	170.71	37.33	38.01	924.24
1958	36.74	36.10	30.52	26.39	20.86	21.08	24.02	188.54	201.46	51.12	30.78	24.18	691.78
1959	20.48	29.78	30.37	23.87	21.30	24.45	30.22	54.15	348.16	146.31	35.52	23.85	788.45
1960	41.44	35.54	27.77	19.49	18.91	28.39	30.03	60.14	218.16	37.08	21.90	10.38	549.22
1961	20.74	26.84	23.83	22.62	18.98	18.48	7.00	85.18	240.26	36.02	11.04	55.47	566.45
1962	49.94	34.82	26.18	19.74	22.27	22.07	52.75	106.74	289.06	126.61	53.31	35.88	839.36
1963	33.32	29.83	29.68	20.92	32.48	22.62	25.40	139.04	286.96	97.61	17.21	36.65	771.71
1964	25.21	28.75	24.09	18.85	18.02	19.38	29.59	116.24	260.86	186.21	26.85	17.26	771.30
1965	22.32	31.28	28.55	27.56	23.57	19.64	35.05	92.61	339.76	206.51	73.63	48.39	948.86
1966	45.34	33.91	30.13	24.11	18.83	23.06	24.63	112.94	169.06	67.35	22.72	25.03	597.10
1967	28.45	28.84	26.17	26.07	21.18	21.55	20.79	111.04	378.16	241.71	48.99	28.60	981.54
1968	42.38	36.08	27.93	25.90	23.86	25.62	21.64	45.39	281.16	130.11	80.87	46.68	787.61
1969	37.57	30.95	25.28	24.23	21.79	21.95	40.08	138.74	195.06	100.81	19.68	16.82	672.95
1970	29.99	29.89	27.12	23.81	22.25	21.49	20.45	137.64	307.76	125.51	25.14	39.22	810.26
1971	37.93	30.57	27.46	23.72	24.91	24.75	29.22	126.74	361.06	188.11	62.48	56.91	993.85
1972	50.98	37.34	30.43	28.88	28.43	36.69	28.00	112.61	380.04	144.15	75.56	56.03	1009.13
1973	58.20	39.99	28.83	27.80	25.50	24.32	33.35	101.78	188.73	93.73	28.95	52.25	703.41
1974	36.26	36.29	24.73	30.17	21.94	24.74	38.78	98.69	395.52	189.92	61.79	36.57	995.39
1975	29.91	33.29	27.05	17.95	19.44	31.68	30.43	100.22	255.20	344.15	69.14	31.46	989.92
AVG	33.03	30.10	25.78	22.50	20.85	23.79	31.50	116.55	252.38	127.86	37.81	30.66	752.82

TABLE B-4

YELLOWSTONE RIVER AT BILLINGS: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						UNITS - 1000AF							
1929	299.79	252.65	209.98	181.5c	153.93	263.51	245.41	580.63	1301.96	804.65	269.74	214.80	4778.55
1930	211.79	171.65	145.98	136.5c	194.93	184.51	314.41	525.43	897.76	466.65	394.74	235.80	3860.15
1931	295.79	180.65	143.98	149.5c	141.93	152.51	170.41	434.43	939.76	194.65	154.74	140.80	3099.15
1932	190.79	140.65	138.98	116.5c	90.63	213.51	157.41	705.53	1481.86	774.65	232.74	185.80	4429.05
1933	199.79	180.65	100.18	95.0c	92.53	160.51	171.41	464.53	1541.86	427.65	215.74	229.80	3879.65
1934	184.79	151.85	156.68	186.0c	131.23	153.51	278.41	619.43	567.86	172.35	86.54	102.60	2831.25
1935	158.49	144.15	129.68	131.3c	136.93	126.11	152.81	418.43	1308.86	728.45	215.64	146.50	3797.35
1936	156.39	183.95	143.58	143.4c	121.83	152.41	290.31	931.43	1078.86	321.15	222.54	153.90	3899.75
1937	178.39	168.05	124.38	115.4c	105.33	182.31	154.81	624.43	1186.96	480.95	145.64	121.10	3587.75
1938	199.29	163.95	120.48	179.9c	107.43	160.51	170.61	646.43	1745.96	893.15	283.14	191.20	4862.05
1939	222.29	219.55	163.18	134.7c	102.73	212.81	255.91	855.33	952.06	451.05	177.14	129.50	3876.25
1940	170.89	150.75	131.98	85.3c	104.83	136.01	170.61	713.53	1117.06	318.85	96.64	119.40	3315.85
1941	207.39	160.95	134.08	116.7c	112.23	129.31	160.01	561.03	910.76	352.45	219.24	396.50	3460.65
1942	422.09	284.55	220.18	180.6c	154.13	242.41	350.61	798.83	1462.66	874.25	262.34	207.50	5456.15
1943	232.29	228.05	205.78	160.6c	222.93	329.91	522.61	794.13	2196.86	1616.15	489.34	316.40	7315.05
1944	249.49	228.25	191.08	162.8c	139.73	177.91	147.31	521.13	1707.66	1012.05	261.14	250.60	5049.15
1945	233.09	208.15	142.78	159.4c	126.53	165.51	158.71	463.93	1485.26	1213.85	399.44	261.00	5017.65
1946	262.99	240.15	168.58	198.7c	187.33	196.71	330.41	640.33	1236.26	607.25	205.44	216.10	4490.25
1947	271.69	214.65	179.98	161.5c	127.23	194.21	273.91	1047.03	1490.36	990.95	384.04	274.90	5610.45
1948	299.99	240.45	204.88	164.0c	155.93	199.01	234.01	1040.13	2142.66	745.45	317.94	180.60	5925.05
1949	208.79	189.75	134.48	119.8c	132.53	181.61	290.11	949.43	1329.66	553.95	203.24	210.10	4503.45
1950	244.69	206.25	124.18	88.5c	116.43	193.51	207.31	534.43	1639.56	1302.15	462.84	295.00	5414.85
1951	331.99	292.95	249.58	173.5c	198.13	231.21	271.11	901.73	1230.86	1085.15	576.34	308.90	5851.45
1952	317.19	268.25	184.18	163.4c	157.73	186.71	408.71	1238.83	1612.06	720.25	355.94	212.20	5825.45
1953	192.29	179.35	166.38	172.2c	140.43	149.41	165.91	334.13	1464.86	821.35	305.54	180.60	4272.45
1954	173.49	190.45	173.18	122.1c	149.93	139.11	198.71	851.13	1080.06	932.75	301.94	182.90	4495.75
1955	189.59	187.85	159.38	134.4c	114.23	142.71	236.41	458.83	1193.66	600.65	231.44	151.70	3800.85
1956	187.19	170.05	172.28	160.8c	145.13	249.81	309.71	1216.03	1912.96	727.45	324.54	212.40	5788.35
1957	190.39	211.05	176.98	100.8c	142.73	186.41	187.11	968.43	2244.46	1067.25	311.14	276.10	6062.85
1958	263.59	235.85	193.48	152.7c	134.53	158.51	180.31	961.43	1140.26	451.05	219.14	167.50	4258.35
1959	169.39	198.25	176.68	141.0c	124.63	178.31	215.41	506.63	1951.26	879.75	265.34	196.40	5003.05
1960	269.49	231.35	193.48	118.5c	138.93	177.91	209.31	406.03	1173.66	338.25	194.64	132.50	3584.05
1961	164.99	181.85	151.18	135.7c	132.93	124.51	85.11	427.83	1116.66	279.85	122.14	277.10	3199.85
1962	309.09	273.25	195.48	145.5c	221.33	214.11	358.91	810.43	1730.66	905.55	405.94	294.80	5865.05
1963	248.29	216.65	186.58	133.0c	228.43	162.81	182.81	783.03	1792.66	675.55	231.84	239.30	5080.95
1964	199.89	200.35	153.18	145.6c	152.13	148.91	202.01	709.23	1719.66	1147.35	344.54	222.20	5345.05
1965	189.19	204.55	185.98	209.6c	185.13	173.21	305.81	690.93	2088.76	1462.25	566.84	402.90	6665.15
1966	356.09	255.55	200.28	181.2c	171.43	202.91	236.41	815.03	969.56	467.05	209.94	195.30	4260.75
1967	213.29	216.35	192.48	190.2c	164.13	196.21	185.91	682.93	2445.76	1600.15	400.44	241.80	6729.65
1968	300.59	250.15	196.38	164.8c	222.33	227.11	220.21	475.03	2032.86	1133.15	567.04	427.90	6217.55
1969	341.29	275.25	201.38	178.8c	180.03	225.51	362.71	973.83	1325.76	942.65	282.74	197.50	5487.45
1970	252.69	225.65	189.68	156.4c	159.83	167.31	183.41	1014.93	2174.96	1021.45	329.14	342.60	6218.05
1971	302.69	239.35	190.78	189.9c	227.03	195.91	284.01	899.43	2216.96	1298.35	457.74	391.00	6893.15
1972	349.43	270.66	201.76	162.7c	198.91	301.29	235.07	718.84	1958.36	872.91	477.52	393.17	6140.67
1973	391.17	285.77	201.45	192.6c	171.48	201.67	290.92	858.64	1256.45	643.47	248.80	323.05	5065.51
1974	265.41	244.08	199.93	191.1c	147.45	178.64	275.88	617.15	2438.16	1322.03	491.49	299.23	6670.65
1975	257.65	245.89	182.12	150.4c	123.63	213.92	307.14	912.37	1955.56	2282.59	553.88	295.61	7480.79
AVG	245.26	214.90	171.68	151.8c	150.81	188.14	240.56	725.59	1530.84	829.38	308.00	237.12	4994.09

TABLE B-5

BIGHORN RIVER NEAR ST. XAVIER: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						UNITS - 1000AF							
1935	133.90	140.56	125.86	152.46	152.26	152.45	131.47	134.02	156.28	268.42	124.19	127.65	1799.55
1936	139.20	141.37	119.86	200.96	200.76	200.95	126.87	122.12	141.58	55.82	125.09	128.55	1703.15
1937	138.20	140.27	119.46	232.06	231.86	232.05	152.07	155.72	182.18	333.42	130.79	134.25	2182.35
1938	139.60	140.67	124.26	212.46	212.26	212.45	134.67	137.32	160.18	252.22	134.19	137.75	1998.05
1939	140.20	141.17	133.56	228.86	228.66	228.85	126.57	108.92	110.28	0.00	114.39	121.15	1682.63
1940	140.90	142.97	120.56	167.76	167.56	167.75	126.97	110.42	111.38	0.00	114.49	122.15	1492.93
1941	140.80	142.17	120.56	196.66	196.46	196.65	127.27	109.22	123.08	70.22	171.89	175.25	1770.25
1942	170.20	178.67	177.86	268.06	267.86	268.05	251.47	260.02	309.58	173.62	130.09	133.55	2589.05
1943	139.20	140.67	122.46	260.18	259.96	260.15	265.27	274.52	327.88	666.12	137.79	141.25	2995.45
1944	139.40	143.37	142.56	261.58	261.36	261.55	355.67	369.42	443.78	318.92	121.49	124.95	2944.05
1945	137.60	139.97	119.46	207.58	207.36	207.55	161.57	165.62	194.78	422.02	180.39	183.85	2327.75
1946	178.90	187.37	186.46	261.36	261.16	261.35	160.17	164.22	192.28	150.42	150.39	153.85	2307.95
1947	148.90	157.47	156.66	262.86	262.66	262.85	296.07	306.92	366.68	634.02	167.19	170.55	3192.85
1948	165.60	174.27	173.36	307.16	306.96	307.15	222.57	229.72	272.68	137.22	122.29	125.75	2544.75
1949	137.30	139.67	119.26	238.86	238.66	238.85	184.37	189.52	223.58	112.82	131.79	135.25	2089.95
1950	139.30	140.47	127.26	251.56	251.36	251.55	155.87	159.62	186.78	384.72	178.79	182.35	2409.65
1951	177.40	185.97	185.16	284.16	283.96	284.15	202.87	209.02	247.38	577.62	183.89	187.25	3008.85
1952	182.20	190.67	189.76	281.26	281.06	281.25	264.37	273.52	326.08	107.32	119.89	123.25	2620.65
1953	139.30	141.47	119.96	210.66	210.47	210.65	126.97	127.92	148.48	50.72	118.79	122.25	1727.65
1954	139.30	141.07	119.76	208.28	208.06	208.25	126.87	108.62	109.88	131.22	117.59	121.05	1739.95
1955	139.40	141.07	119.76	173.89	173.67	173.85	126.97	118.92	137.28	80.42	111.99	119.15	1616.35
1956	138.30	141.27	120.66	196.49	196.27	196.45	245.87	254.12	303.08	139.12	116.99	120.45	2169.05
1957	138.90	141.27	119.96	229.48	229.26	229.45	307.47	318.92	382.48	461.62	164.09	167.65	2890.55
1958	162.70	171.37	170.76	248.29	248.07	248.25	154.47	158.22	184.88	33.02	122.39	125.75	2028.15
1959	138.10	140.47	119.66	214.09	213.86	214.05	126.57	109.02	110.28	98.52	132.59	136.05	1753.25
1960	139.60	140.87	129.36	212.49	212.27	212.45	126.47	110.82	112.18	0.00	120.49	128.15	1645.13
1961	148.00	155.07	134.66	122.99	124.07	133.35	137.07	118.22	115.88	0.00	133.79	141.85	1464.93
1962	172.30	140.57	102.56	135.59	135.77	137.05	191.37	197.02	233.08	276.22	140.89	144.35	2006.75
1963	139.30	147.87	146.96	247.68	247.47	247.65	262.17	271.32	324.28	188.22	140.59	144.05	2507.55
1964	148.70	147.67	146.76	240.49	240.26	240.45	267.07	276.42	330.18	432.62	137.89	141.35	2749.85
1965	147.30	144.27	143.36	261.19	260.97	261.15	326.67	339.02	407.18	754.12	193.59	196.95	3435.75
1966	201.50	200.36	199.36	201.69	201.47	201.65	126.37	109.62	111.38	0.00	117.89	124.95	1796.23
1967	154.50	147.07	129.36	179.69	179.47	179.65	352.27	365.82	440.08	762.22	162.79	166.25	3219.15
1968	170.90	169.77	168.96	261.19	260.97	261.15	245.97	254.22	303.48	165.52	194.89	198.25	2655.25
1969	202.80	201.77	200.86	259.19	258.97	259.15	184.37	189.52	223.18	164.52	132.89	136.25	2413.45
1970	148.00	140.37	131.46	233.99	233.77	233.95	244.57	252.82	301.68	231.82	155.29	158.75	2466.45
1971	163.40	162.67	161.66	283.79	283.57	283.75	318.17	330.12	395.68	468.82	219.59	223.05	3294.25
1972	227.52	226.67	225.77	346.09	345.87	346.06	231.20	239.56	286.14	231.41	201.27	203.70	3111.25
1973	206.84	205.98	205.18	251.79	251.58	251.77	152.22	157.37	185.71	197.33	218.37	220.05	2504.19
1974	222.06	221.09	220.28	260.59	260.39	260.58	247.35	258.02	310.07	467.62	177.65	178.30	3083.99
1975	179.18	178.39	177.79	254.00	253.89	253.99	247.37	260.96	314.04	777.11	116.92	118.25	3131.89
AVG	157.48	158.93	148.27	231.95	231.77	232.20	202.98	205.03	240.17	262.85	146.05	149.89	2367.58

TABLE B-6

TONGUE RIVER AT MILES CITY: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						UNITS = 1000AF							
1938	1.29	.82	.54	.65	.16	0.00	11.76	56.84	89.15	39.91	0.00	0.00	201.11
1939	5.58	11.15	4.97	8.53	10.05	37.13	17.84	3.49	60.22	1.03	0.00	2.43	162.41
1940	19.07	7.95	9.21	7.30	8.15	11.09	2.95	4.79	20.21	7.19	0.00	0.00	97.89
1941	20.29	6.86	7.07	6.99	6.59	7.27	2.75	15.61	47.32	0.00	.25	17.53	138.51
1942	32.89	35.62	20.04	12.45	8.56	26.56	22.45	39.02	100.18	11.05	0.00	7.22	316.03
1943	29.29	31.82	20.04	12.15	19.16	47.16	70.15	47.02	110.18	11.05	0.00	7.22	405.23
1944	18.29	30.32	18.04	10.65	6.16	35.16	29.15	83.02	224.18	105.05	0.00	.72	560.73
1945	16.29	35.32	19.04	12.45	10.16	25.16	20.65	23.02	128.18	49.05	0.00	9.22	348.53
1946	40.29	31.32	16.54	14.65	12.66	52.16	31.55	38.22	107.48	35.55	6.25	20.62	407.27
1947	41.36	34.54	22.06	24.95	18.51	90.86	47.09	83.33	82.07	48.25	2.65	7.43	503.08
1948	18.41	28.44	18.60	15.03	16.98	46.99	42.57	65.32	83.68	67.60	7.36	3.56	414.52
1949	19.84	33.72	11.17	10.24	6.44	84.67	28.97	46.27	62.25	.36	0.00	.13	304.05
1950	11.60	27.51	26.52	10.93	8.78	21.23	24.00	29.46	32.64	14.35	3.52	12.57	223.09
1951	22.44	24.97	13.69	13.29	12.48	13.74	14.05	25.74	28.09	23.36	12.41	26.81	231.05
1952	21.48	32.32	12.23	8.99	9.46	31.16	86.70	61.94	55.06	10.45	2.16	4.99	336.92
1953	21.87	13.96	13.22	11.65	9.21	13.06	8.35	22.56	98.38	1.84	0.00	0.00	214.08
1954	16.84	24.22	12.67	11.43	14.46	13.79	13.27	12.62	10.77	0.00	3.62	.34	134.01
1955	6.03	13.37	13.24	9.93	5.90	15.71	26.80	47.85	67.49	20.20	.12	0.00	226.62
1956	3.72	8.52	9.88	10.31	9.17	29.49	52.65	34.69	55.77	0.00	2.91	1.87	218.96
1957	5.93	18.22	14.30	8.56	7.86	14.53	21.67	25.73	112.68	28.87	2.31	15.35	275.99
1958	16.55	10.55	10.61	10.69	9.50	14.05	12.00	28.30	30.85	27.74	.81	.09	171.72
1959	14.55	15.96	15.45	12.58	10.68	91.05	31.77	23.78	16.70	3.02	9.41	9.42	254.35
1960	8.21	10.78	13.44	12.25	11.00	49.72	19.75	1.15	0.00	0.00	0.00	0.00	126.28
1961	1.83	6.24	4.86	5.28	5.70	4.77	.69	0.00	0.00	0.00	0.00	2.51	31.87
1962	6.10	5.43	8.71	8.91	15.33	34.70	36.65	45.73	121.08	18.55	4.00	11.21	316.38
1963	15.79	12.96	11.09	8.75	38.48	28.27	13.74	82.98	168.08	16.29	3.82	9.46	409.70
1964	2.76	5.59	5.02	9.31	10.62	12.04	18.13	47.87	143.88	52.24	12.64	14.78	334.86
1965	13.98	12.47	11.07	14.16	26.87	37.10	100.75	57.12	76.48	40.23	8.14	17.08	415.43
1966	36.45	20.45	12.09	9.41	8.06	15.53	8.37	8.57	9.14	2.75	1.54	4.22	136.56
1967	2.64	5.96	6.80	10.13	13.19	19.24	20.52	35.75	204.98	63.53	8.33	16.92	407.97
1968	14.70	19.88	14.98	17.80	30.69	47.86	26.84	30.04	159.68	37.19	32.23	33.75	465.62
1969	33.45	19.04	12.62	12.91	12.06	93.11	62.51	65.22	45.64	52.47	6.90	9.46	425.37
1970	12.83	8.79	13.97	13.48	14.76	25.09	35.92	91.74	157.38	27.84	5.65	10.98	418.42
1971	16.79	17.18	13.04	11.87	99.77	109.76	58.50	69.58	97.88	11.24	3.49	11.92	521.00
1972	43.00	21.61	12.57	10.57	18.48	95.22	56.70	45.85	80.02	19.10	12.51	14.13	429.76
1973	23.31	20.53	10.70	14.67	15.61	17.28	18.71	83.09	114.35	23.31	10.22	22.50	374.27
1974	29.09	23.86	10.34	26.10	20.14	18.69	20.61	46.12	74.49	20.38	10.79	7.93	308.53
1975	14.34	18.21	19.98	30.89	10.03	60.08	49.92	109.21	161.23	135.13	42.46	15.23	666.70
AVG	17.87	18.59	12.90	12.13	15.05	36.59	30.72	43.12	85.20	27.01	5.69	9.20	314.08

TABLE B-7

YELLOWSTONE RIVER NEAR MILES CITY: 1975 LEVEL OF DEVELOPMENT FLOWS

UNITS - 1000AF

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1929	543.90	539.62	458.71	413.64	383.55	1176.51	561.26	1274.39	1892.24	1080.25	339.36	372.70	9036.14
1930	408.60	359.72	346.01	309.54	327.75	567.90	507.86	745.49	977.94	591.55	775.78	413.30	6531.44
1931	632.00	514.12	408.41	376.74	393.15	378.40	353.66	646.99	1030.24	160.35	288.18	246.40	5430.64
1932	360.10	307.32	262.01	272.94	206.95	464.20	455.76	1212.09	1706.14	1050.85	294.16	271.90	6874.44
1933	423.70	410.22	284.81	304.44	241.95	569.60	458.16	972.29	1856.54	541.55	291.08	371.00	6875.34
1934	373.10	422.42	338.01	400.24	435.05	376.30	360.46	648.99	437.54	118.85	154.58	200.20	4305.74
1935	317.70	319.72	262.51	288.04	325.45	344.00	303.36	535.19	1498.54	1132.55	305.98	253.60	5886.64
1936	297.50	321.92	259.41	301.04	301.65	606.90	426.76	1003.09	1242.54	352.25	296.08	269.20	5678.34
1937	327.50	327.52	227.51	281.64	314.25	520.70	349.56	627.99	1413.24	791.45	239.88	228.90	5650.34
1938	383.20	334.02	283.41	397.44	352.95	530.10	345.66	803.09	2114.54	1433.65	433.28	329.70	7741.04
1939	401.40	423.82	317.31	417.84	313.15	516.50	404.36	818.19	1279.44	453.35	262.18	216.40	5823.94
1940	365.10	301.32	249.71	241.44	297.05	365.20	347.66	740.89	1319.84	294.85	168.28	188.50	4879.84
1941	418.80	303.72	274.41	321.84	332.65	388.10	326.16	675.39	1117.24	397.45	370.38	739.80	5665.94
1942	724.50	546.32	461.31	453.24	446.75	634.20	645.56	1123.19	1941.74	1092.15	393.28	333.30	8795.54
1943	432.20	410.02	344.41	423.14	644.05	881.60	920.26	1073.79	2664.14	2342.05	686.98	480.60	11303.24
1944	441.40	436.02	376.01	434.24	394.85	661.80	591.06	977.99	2634.74	1606.65	439.58	399.60	9593.94
1945	430.80	414.82	279.31	405.84	386.15	553.80	372.46	635.49	1858.94	1741.95	584.18	449.50	8113.24
1946	533.80	474.52	348.91	500.64	464.05	561.50	509.96	810.59	1593.64	784.25	339.88	444.60	7366.34
1947	510.40	440.42	347.31	353.14	352.05	621.20	695.76	1401.39	1870.74	1655.25	540.06	441.60	9229.34
1948	538.00	480.32	415.81	481.64	460.85	676.80	580.56	1201.19	2622.34	1117.55	441.78	275.40	9292.24
1949	402.50	414.82	228.71	305.14	361.35	649.20	561.16	1101.19	1660.74	701.15	292.68	342.50	7021.14
1950	421.80	408.42	250.61	321.34	380.65	708.00	581.86	707.99	1848.44	1755.55	672.98	496.00	8553.64
1951	602.80	512.82	453.91	460.34	470.65	685.90	568.06	1051.39	1616.64	1664.25	828.48	571.10	9486.34
1952	565.60	518.72	410.51	460.54	470.95	675.30	804.26	1546.49	1971.64	878.15	477.08	349.70	9128.94
1953	393.00	362.92	290.91	420.74	372.45	435.11	327.16	496.99	1816.54	851.55	404.08	280.10	6451.54
1954	350.80	378.92	326.91	336.44	418.45	390.30	351.76	935.39	1128.14	1057.55	406.38	273.30	6354.34
1955	364.20	365.52	303.51	309.34	322.45	321.61	516.46	673.09	1386.24	686.25	291.98	232.20	5772.84
1956	355.60	316.52	338.41	391.44	379.85	614.10	630.76	1371.79	2358.34	828.95	407.18	335.10	8328.04
1957	365.90	424.52	313.31	339.84	382.25	489.90	590.86	1272.69	2816.34	1647.85	452.78	495.30	9591.54
1958	465.00	463.92	395.21	437.94	465.45	480.50	373.86	1066.79	1499.64	580.35	305.88	274.80	6769.34
1959	353.40	365.42	313.21	372.34	365.85	783.00	396.16	608.79	1913.54	929.45	350.58	325.50	7077.24
1960	451.70	403.72	381.71	341.64	386.65	560.11	381.76	471.69	1184.74	245.85	266.08	233.20	5308.84
1961	344.80	369.42	276.11	301.64	295.65	299.61	225.36	415.19	1217.94	203.95	183.08	423.10	4555.84
1962	539.50	465.12	279.91	303.84	439.45	469.81	583.96	1029.99	2113.54	1284.15	522.18	461.40	8492.84
1963	480.80	402.12	358.11	407.74	581.85	500.70	488.46	1116.69	2256.14	874.05	311.18	400.80	8158.64
1964	356.70	379.32	290.91	416.54	430.25	401.90	547.76	1050.89	2272.34	1753.65	485.08	414.90	8800.24
1965	382.30	391.12	351.01	536.34	517.25	557.70	890.76	1110.69	2453.64	2299.15	777.38	676.60	10943.94
1966	640.70	523.12	411.91	352.94	411.45	631.10	429.46	799.59	1120.14	401.65	283.28	305.80	6311.14
1967	404.20	372.92	309.71	398.74	393.55	445.20	568.26	1040.09	3120.64	2421.05	549.68	450.60	10474.64
1968	511.40	467.92	349.31	485.74	643.75	632.90	533.06	737.99	2572.04	1406.35	809.98	671.40	9821.84
1969	605.00	505.42	371.21	468.64	470.25	810.90	707.46	1292.09	1654.64	1282.25	388.78	322.70	8879.34
1970	437.30	403.92	342.91	426.94	501.45	529.51	537.36	1468.99	2681.44	1432.75	459.58	507.80	9729.94
1971	525.60	453.62	346.11	529.34	986.05	809.51	772.16	1218.99	2634.54	1788.55	641.38	657.10	11362.94
1972	708.84	526.68	422.51	496.06	627.60	1143.27	583.15	1058.76	2372.85	1160.74	694.06	606.88	10401.40
1973	657.98	553.04	368.31	501.57	509.95	551.13	561.25	1227.60	1583.88	879.77	456.38	613.06	8463.91
1974	571.32	557.70	488.11	487.98	458.60	484.99	583.53	933.08	2912.50	1928.08	683.37	523.03	10612.30
1975	492.66	529.05	393.81	469.39	420.25	675.94	688.72	1520.16	2388.84	3052.38	758.66	429.02	11818.89
AVG	459.47	423.93	338.55	392.76	426.56	579.42	517.05	963.72	1868.69	1122.21	442.66	395.73	7930.75

TABLE B-8

POWDER RIVER AT ARVADA: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						UNITS - 1000AF							
1929	7.96	10.58	0.00	0.00	0.00	141.28	80.50	115.56	72.88	28.32	7.49	4.41	468.98
1930	9.68	.18	0.00	0.00	0.00	32.48	29.30	31.56	8.88	8.02	30.60	5.70	156.40
1931	15.98	6.67	5.74	5.99	7.01	13.58	11.20	37.06	24.08	7.17	10.90	2.30	147.68
1932	3.69	6.04	3.55	3.32	24.13	36.98	23.00	89.66	66.28	7.50	0.00	0.00	264.15
1933	2.39	8.45	3.86	.86	0.00	23.88	36.70	122.16	53.58	.48	28.60	18.13	299.09
1934	7.07	10.78	0.00	0.00	0.00	0.00	20.76	2.00	12.65	13.36	.80	3.65	71.07
1935	3.75	5.14	2.32	1.78	10.45	13.83	11.11	24.79	62.17	5.66	6.18	.46	147.65
1936	.16	.85	6.08	3.29	10.82	52.43	5.63	0.00	35.02	16.41	0.00	0.00	130.70
1937	4.03	8.19	4.41	1.54	2.01	30.81	28.97	19.40	62.59	102.32	1.84	10.84	276.95
1938	10.99	4.48	4.16	5.78	6.07	20.00	17.00	49.43	21.47	28.84	.07	4.11	172.40
1939	1.65	5.15	8.32	7.96	3.70	29.03	10.10	19.87	19.34	0.00	0.00	0.00	105.08
1940	4.56	4.74	6.79	3.79	8.40	17.73	19.24	12.06	19.35	4.82	0.00	1.15	102.63
1941	25.17	4.24	5.62	5.40	6.33	10.66	64.37	77.89	22.80	48.24	51.62	13.18	335.52
1942	16.59	13.54	11.36	5.06	6.41	15.63	29.68	43.27	14.33	2.47	7.18	.20	165.68
1943	6.09	7.73	5.41	6.75	8.62	38.22	41.19	36.49	54.19	9.20	0.00	0.00	213.89
1944	2.85	5.29	4.12	2.63	3.03	8.43	32.98	95.75	90.54	22.28	2.32	0.00	270.23
1945	6.16	7.33	6.70	6.07	8.12	31.10	37.99	34.25	60.99	22.91	9.75	6.28	237.65
1946	9.18	10.62	5.89	9.14	11.70	18.14	23.08	25.67	32.55	20.07	0.00	8.97	175.01
1947	8.59	9.61	7.36	5.52	9.37	56.96	18.41	82.94	42.46	18.58	0.00	.64	260.44
1948	4.97	8.74	6.39	4.98	12.00	51.69	13.47	29.16	74.40	22.26	3.24	2.62	233.92
1949	7.70	7.74	4.98	3.56	3.52	52.82	18.11	30.46	36.34	5.70	0.00	0.00	170.93
1950	5.25	5.40	1.17	1.74	2.74	12.29	21.18	50.64	16.13	1.82	0.00	0.00	118.36
1951	5.94	6.59	2.15	3.82	4.08	13.35	8.47	15.52	2.30	0.00	2.81	17.55	82.58
1952	6.87	6.27	4.35	2.10	5.09	13.89	20.96	70.52	12.12	8.93	.98	0.00	152.09
1953	1.25	3.93	2.71	4.83	5.92	17.13	9.11	6.71	34.10	2.18	12.33	0.00	100.21
1954	0.00	2.90	3.22	3.37	11.17	13.03	14.77	12.96	0.00	2.50	7.05	0.00	70.98
1955	.22	3.55	1.85	2.21	2.90	42.97	29.45	27.61	40.64	7.35	10.53	.10	169.38
1956	1.25	2.40	12.25	5.82	6.53	36.32	13.98	18.85	12.85	4.26	2.69	0.00	117.21
1957	0.00	2.17	4.19	3.50	1.64	12.77	12.79	27.08	62.56	12.86	1.16	2.68	143.40
1958	5.77	7.88	6.56	5.22	4.26	11.56	15.04	27.41	19.73	26.59	2.71	0.00	132.74
1959	.99	4.94	3.85	3.69	3.24	20.93	9.77	27.34	21.95	10.49	0.00	0.00	107.19
1960	1.95	2.33	3.99	2.78	4.74	36.09	13.45	5.39	3.30	.90	.07	0.00	74.99
1961	0.00	1.66	1.60	2.25	2.56	7.84	4.79	13.33	3.32	1.92	0.00	.19	39.45
1962	9.43	5.94	2.21	1.93	25.22	14.62	23.94	122.76	195.38	47.77	13.54	10.86	473.60
1963	23.17	10.21	8.55	7.22	14.38	13.20	13.38	32.67	52.39	9.48	.58	10.18	195.41
1964	3.77	6.47	4.66	5.45	4.01	12.15	26.96	37.67	101.58	18.77	.35	0.00	221.85
1965	2.43	6.38	5.81	8.71	13.04	28.73	40.11	45.94	63.76	27.48	8.36	4.78	255.53
1966	8.39	7.75	5.00	4.38	5.24	20.37	15.71	16.75	5.60	.82	0.00	6.48	96.49
1967	2.67	6.02	3.64	4.48	6.13	12.42	10.28	29.55	159.58	46.70	4.53	6.94	292.94
1968	8.18	8.98	4.64	4.52	7.24	21.17	13.31	43.75	126.28	19.73	11.14	10.78	279.72
1969	10.22	8.52	6.90	8.65	6.69	18.59	14.70	17.44	14.61	9.24	0.00	0.00	115.56
1970	3.01	6.44	4.37	5.57	8.79	16.17	12.30	66.71	48.99	11.12	0.00	0.00	183.47
1971	4.92	7.69	6.38	4.34	8.48	36.21	16.41	52.79	53.97	3.63	0.00	.51	195.34
1972	6.84	8.92	6.14	5.06	32.08	37.93	20.44	48.36	36.90	5.26	10.76	5.38	224.07
1973	9.44	8.67	4.61	5.41	7.25	19.87	39.24	78.56	26.81	24.79	4.68	18.88	248.19
1974	13.34	17.96	17.76	14.84	11.60	16.75	39.28	21.58	7.63	.50	1.67	.55	163.46
1975	5.72	8.25	5.81	4.74	4.82	15.88	20.93	41.07	101.41	28.57	4.05	1.06	242.30
AVG	6.39	6.68	5.06	4.47	7.48	25.91	22.42	41.24	44.91	15.50	5.55	3.82	189.42

TABLE B-9

POWDER RIVER NEAR LOCATE: 1975 LEVEL OF DEVELOPMENT FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
						(ACRE-FEET - 1000'S)							
1939	4.25	8.87	9.79	8.91	4.05	125.83	23.04	30.77	54.22	6.86	0.00	0.00	277.00
1940	3.01	4.01	5.75	2.10	1.40	27.42	25.72	16.71	36.29	28.62	9.23	1.93	162.76
1941	56.55	9.11	13.03	8.03	10.43	22.05	63.17	166.19	69.47	38.56	64.71	51.71	572.03
1942	39.30	21.65	25.83	6.32	10.87	60.77	44.66	77.47	73.73	6.93	12.56	0.00	380.44
1943	9.50	8.35	10.05	11.67	213.17	152.63	69.73	54.25	146.25	37.74	5.46	4.82	723.81
1944	3.65	4.75	6.54	4.05	2.55	232.03	129.34	180.79	469.44	88.62	11.69	3.74	1141.74
1945	6.47	10.35	8.50	5.40	15.32	61.02	39.13	43.56	146.43	52.79	23.95	14.53	429.02
1946	15.75	13.95	9.89	16.53	62.64	59.96	41.58	66.15	97.78	56.49	10.38	24.08	435.22
1947	42.41	19.37	20.36	15.57	37.63	198.63	67.21	132.79	100.68	49.66	2.30	0.00	686.61
1948	7.55	9.99	10.21	6.40	102.17	206.93	34.86	56.48	126.16	74.57	17.28	3.20	655.89
1949	12.59	16.54	5.48	4.51	3.36	226.93	45.31	57.86	79.71	11.96	0.00	0.00	466.37
1950	8.93	13.37	3.86	.37	0.00	1.46	69.08	80.17	53.32	13.24	3.08	0.00	246.91
1951	10.94	7.49	8.07	5.22	5.37	26.02	22.61	20.69	11.05	5.66	19.48	35.82	182.24
1952	16.60	19.60	23.71	8.12	11.74	103.63	108.24	90.16	44.35	22.37	4.26	1.60	451.41
1953	3.25	6.23	6.31	7.62	10.77	31.98	14.39	22.12	108.74	3.36	26.36	0.00	243.17
1954	4.48	4.50	7.93	7.44	19.54	24.98	13.29	22.31	.83	0.00	16.80	10.09	132.20
1955	.53	3.86	5.39	4.08	3.52	33.06	85.77	46.40	59.77	25.31	10.25	0.00	277.96
1956	.69	2.67	4.80	7.35	4.84	73.73	27.36	40.04	40.70	3.29	6.59	.44	212.55
1957	.43	4.11	7.19	5.44	4.15	23.37	17.85	19.33	133.92	33.39	2.34	4.03	255.61
1958	7.70	11.54	7.79	9.71	10.14	18.04	21.92	43.38	51.84	52.36	12.29	0.00	246.71
1959	3.88	5.21	8.95	6.62	6.64	141.83	26.09	31.31	34.71	17.18	0.00	0.00	302.43
1960	4.09	6.70	10.32	6.55	8.54	125.73	26.15	2.34	3.77	0.00	0.00	0.00	194.23
1961	0.00	.67	.78	1.31	1.78	16.04	4.03	1.74	4.14	0.00	0.00	3.06	33.73
1962	7.05	5.44	3.10	2.17	76.54	51.56	39.42	133.29	262.14	118.46	24.00	11.34	735.06
1963	28.48	16.49	9.93	7.68	53.00	43.95	24.88	59.87	191.08	46.37	2.31	12.68	506.70
1964	7.52	11.48	5.78	7.42	6.72	28.42	32.10	40.97	188.08	65.04	5.07	1.89	400.50
1965	2.53	4.78	5.76	10.43	15.12	14.95	180.24	64.47	107.58	43.65	13.87	8.85	472.24
1966	16.15	13.31	7.76	8.29	7.16	29.95	24.23	20.63	2.33	2.55	0.00	2.79	135.21
1967	4.40	5.01	5.64	5.94	10.45	31.93	21.75	69.34	295.64	104.16	8.43	22.92	585.46
1968	15.36	16.26	6.97	6.48	25.69	120.33	30.41	50.51	217.28	41.44	38.55	29.46	598.75
1969	17.64	18.76	8.22	11.28	8.17	135.93	73.54	40.44	27.95	46.71	3.84	0.00	413.50
1970	3.65	11.37	5.86	7.15	14.17	54.77	32.24	110.29	130.44	24.01	.51	0.00	394.50
1971	6.09	13.33	7.20	5.36	112.57	177.33	69.58	71.74	154.44	16.40	.29	1.22	635.60
1972	54.02	22.12	6.16	7.91	78.32	283.67	41.40	61.34	90.03	26.45	21.20	17.92	711.03
1973	20.31	21.69	8.84	11.45	13.45	37.15	43.70	118.18	99.05	26.06	15.46	38.37	451.71
1974	20.66	18.80	8.45	28.19	32.27	45.33	54.75	59.31	39.38	9.49	7.14	8.33	332.29
1975	15.95	19.11	12.49	10.98	13.04	59.34	50.68	122.11	170.52	95.74	11.37	2.78	584.11
AVG	13.05	11.00	8.67	7.79	26.73	84.62	47.10	63.40	106.06	35.11	11.11	8.58	423.42

TABLE B-10

YELLOWSTONE RIVER NEAR SIDNEY: 1975 LEVEL OF DEVELOPMENT FLOWS

UNITS - 1000AF

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1929	549.64	574.79	466.08	418.63	357.04	1330.19	914.68	1281.43	2046.49	1012.19	363.22	384.25	9699.03
1930	497.34	441.39	419.88	373.53	743.24	826.09	645.78	775.03	804.09	497.89	685.02	477.35	7186.63
1931	686.74	579.59	466.08	396.63	414.64	427.39	414.38	618.23	1137.09	118.29	236.12	171.15	5666.33
1932	383.84	325.79	239.68	272.93	265.44	513.49	564.98	1291.93	1703.59	1118.99	318.22	324.65	7343.53
1933	472.44	430.39	306.18	314.43	299.44	741.59	515.08	1152.93	1964.79	561.89	264.92	433.55	7589.63
1934	373.74	453.39	306.48	372.73	300.54	375.39	376.69	680.03	357.79	60.59	118.92	150.15	3907.23
1935	337.54	319.09	257.38	257.13	267.04	391.59	435.18	902.23	1490.59	1191.89	314.22	211.85	5935.73
1936	301.94	321.09	272.08	329.23	304.44	751.19	441.38	979.03	1240.99	353.59	242.52	225.35	5802.83
1937	329.04	353.19	253.38	284.13	321.54	517.09	410.18	577.53	1720.79	1048.89	220.22	198.05	6234.03
1938	397.44	326.19	244.38	404.53	326.54	653.19	379.78	765.73	2317.39	1591.89	441.22	327.15	8175.43
1939	386.74	410.09	294.98	434.83	367.34	786.69	413.38	847.63	1234.29	398.69	209.32	168.65	5912.63
1940	344.54	322.19	258.78	242.23	309.54	338.39	401.78	710.63	1396.79	271.69	140.72	143.25	4919.53
1941	519.94	297.89	266.88	314.93	347.84	425.99	392.29	736.53	1225.69	404.09	436.82	863.85	6251.73
1942	818.04	579.19	511.08	448.53	480.84	873.29	640.79	1104.93	2028.19	1051.09	378.12	294.05	9208.13
1943	449.54	462.29	298.08	435.83	899.94	1254.19	1097.59	1073.93	2761.89	2567.09	707.82	446.65	12454.83
1944	414.94	447.69	390.58	437.33	421.14	1056.29	890.28	1056.33	3354.69	1695.19	435.12	353.65	10953.23
1945	439.54	427.69	279.48	418.93	400.14	753.99	434.98	624.03	1856.49	1048.89	571.62	435.25	8491.03
1946	546.04	478.09	322.08	529.53	444.24	709.19	495.49	766.63	1588.09	844.59	280.22	460.45	7464.63
1947	596.14	503.99	404.28	397.23	451.54	1207.19	830.78	1472.43	1858.19	1667.19	513.72	394.85	10297.63
1948	550.84	513.29	433.08	484.63	478.04	808.49	681.68	1055.63	2850.29	1262.69	422.82	209.15	9750.63
1949	404.74	433.79	214.28	322.33	354.64	717.19	651.18	976.03	1678.09	683.99	237.32	275.05	6948.63
1950	408.24	412.49	249.68	307.33	405.14	714.09	902.78	869.33	1865.39	1645.29	614.22	440.35	8654.33
1951	569.84	481.69	453.38	473.73	470.74	566.59	736.68	872.03	1529.79	1548.99	789.72	576.85	9140.23
1952	552.54	541.19	316.68	477.53	504.64	765.09	1482.19	1492.23	2022.19	824.29	419.72	291.35	9749.63
1953	357.44	355.09	289.98	413.73	392.14	460.29	316.29	501.23	1961.29	805.39	371.92	217.55	6442.33
1954	329.34	375.39	306.98	287.13	508.94	423.79	472.38	900.53	1015.09	1044.69	416.12	267.55	6347.93
1955	352.74	373.19	312.98	279.23	365.14	345.49	666.39	705.23	1368.89	735.89	253.12	163.85	5882.13
1956	347.14	314.79	306.28	411.63	369.14	778.79	686.58	1229.33	2413.09	802.79	374.12	302.45	8336.13
1957	348.14	438.49	334.88	366.33	366.04	588.99	524.78	1136.53	2854.49	1634.99	397.12	427.55	9520.73
1958	447.54	463.39	369.58	446.93	377.54	584.39	425.48	923.93	1502.39	633.09	243.52	219.35	6645.53
1959	354.24	368.79	300.58	341.83	384.24	1237.39	436.58	575.23	1814.79	454.99	274.12	268.45	7312.73
1960	446.34	374.09	378.38	335.03	425.24	878.39	429.49	422.83	1104.59	186.19	154.42	168.35	5343.33
1961	324.74	363.29	251.18	319.43	299.34	363.69	227.18	284.93	1214.39	139.79	113.25	380.45	4281.66
1962	545.14	451.59	256.48	326.83	537.84	581.39	552.79	1171.63	2461.19	1600.49	526.62	433.55	9545.53
1963	500.44	435.59	386.08	420.53	547.14	669.19	522.58	1252.43	2753.19	986.49	270.02	388.35	9282.03
1964	365.74	359.45	280.48	448.13	409.74	459.79	391.38	1055.53	2499.49	1948.89	488.92	426.25	9433.83
1965	386.64	403.19	310.38	535.23	564.94	519.89	1306.19	1211.93	2779.79	2751.19	788.32	625.95	12245.43
1966	671.54	539.29	442.88	403.73	458.14	774.49	428.68	702.73	1058.99	365.69	244.72	260.05	6350.93
1967	429.74	386.09	342.28	393.53	408.84	512.19	550.48	1104.53	3361.29	2622.89	537.22	461.55	11210.63
1968	561.04	497.79	341.98	533.73	613.94	680.39	572.09	711.83	2718.39	1435.89	748.02	709.25	10374.33
1969	635.54	566.79	421.58	495.53	499.04	1101.19	846.28	1237.03	1625.99	1399.69	329.02	269.45	9427.23
1970	446.24	434.19	365.68	446.53	564.44	670.59	594.18	1501.53	2015.79	1437.99	420.72	464.45	10166.83
1971	531.84	472.65	349.58	574.63	1073.54	1172.29	872.09	1213.63	2905.39	1877.59	594.82	652.05	12340.73
1972	858.66	566.54	388.30	506.24	716.01	1560.58	624.34	1096.17	2480.55	1155.44	664.79	591.89	11309.50
1973	676.58	588.19	409.20	548.03	547.85	985.37	545.27	1309.09	1771.03	874.08	414.75	668.04	9137.50
1974	622.46	540.27	455.37	448.63	485.06	923.05	633.97	938.54	2882.57	1987.49	647.77	518.48	10773.99
1975	536.18	561.92	491.57	475.27	579.31	744.93	807.64	1725.99	2572.77	3258.45	759.04	461.63	12772.31
AVG	476.74	440.15	342.38	403.32	455.67	734.99	620.59	956.08	1956.79	1168.30	414.56	374.55	8345.12

TABLE B-11

MUNICIPAL DEPLETIONS

Yellowstone River

Towns	Station	Diversion (acre-feet)	Return Flow	Depletion
Livingston	Livingston	4,510	2,855	1,655
Big Timber	Billings	365	230	135
Columbus	Billings	883	556	327
Laurel	Billings	7,151	4,505	2,646
Billings	Billings	53,500*	33,705	19,795
Miles City	Miles City	2,889	1,820	1,069
Glendive	Sidney	3,281	2,067	1,214
Broadus	Powder	605	381	224

*Increased in 1980. Originally established at 42,229 acre-feet.

TABLE B-12

IRRIGATION DEPLETIONS

Yellowstone River above Livingston

Crop Requirement: 1.33 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
Park Co. CD					
Pivot	1,369	1,820	2,738	871	1,867
Sideroll	2,858	3,801	5,716	1,819	3,897
Flood	12,890	17,143	42,150	15,004	27,146
Department of State Lands					
9931-r Flood	1,100	1,463	3,300	1,102	2,198
9933-r Flood	253	336	531	117	414
TOTALS	18,470		54,435		35,522

TABLE B-13

IRRIGATION DEPLETIONS

Stillwater River at Absarokee

Crop Requirement: 1.73 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
Stillwater Co. CD					
Pivot	130	245	260	33	277
Sideroll	80	138	160	20	139
Flood	3,412	5,903	11,156	3,152	8,004
TOTALS	3,622		11,576		8,420

TABLE B-14

IRRIGATION DEPLETIONS

Clarks Fork at Edgar

Crop Requirement: 1.82 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
Carbon Co. CD					
Pivot	1,405	2,577	2,824	253	2,570
Sideroll	752	1,368	1,509	133	1,376
Flood	533	970	1,746	466	1,280
Department of State Lands					
9931-r Flood	40	72	120	28	92
9933-r Flood	857	156	2,073	303	1,765
TOTALS	3,587		8,272		7,083

TABLE B-15

IRRIGATION DEPLETIONS

Yellowstone River between Livingston and Billings

Crop Requirement: 1.45 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
Park Co. CD					
Pivot	317	459	634	165	468
Sideroll	744	1,079	1,488	388	1,099
Flood	3,486	5,055	11,399	3,806	7,592
Sweet Grass Co. CD					
Pivot	2,003	2,904	4,507	1,522	2,984
Sideroll	420	609	945	319	626
Flood	6,785	9,838	20,830	6,595	14,235
Northern tributaries	6,105	8,852	19,963	6,666	13,297
Stillwater Co. CD					
Flood below Absarokee	93	135	303	159	143
Pivot	565	819	1,240	900	840
Flood	1,010	1,464	3,636	1,303	2,333
Carbon Co. CD					
Pivot below Silesia	3,552	5,150	7,140	1,890	5,250
Sideroll	2,335	3,386	4,693	1,242	3,451
Flood	1,457	2,113	4,764	1,591	3,173
Yellowstone Co. CD					
Pivot	9,794	14,201	21,840	7,257	14,583
Sideroll	2,008	2,912	4,478	1,488	2,990
Flood	821	1,190	2,258	802	1,725
Department of State Lands					
9931-r					
Flood	434	629	1,302	414	898
9933-r					
Flood	4,044	5,864	12,185	3,793	8,392
9934-r					
Waterspreader	263	197	395	197	198
TOTALS	46,236		124,000		84,277
Waterspreader	263		395		198
Flood	45,973		123,605		84,079

TABLE B-16

IRRIGATION DEPLETIONS

Tongue River above Miles City

Crop Requirement: 1.81 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
Powder River Co. CD	1,250	937	1,875	937	927
Department of State Lands 9934-r Waterspreader	65	48	97	48	48
DNRC for State Lands Flood	607	1,099	1,821	433	1,388
Big Horn Co. CD Flood	470	851	1,034	110	924
Rosebud Co. CD Flood	2,835	5,131	7,144	1,208	5,936
North Custer Co. CD Flood	4,605	8,335	10,987	1,537	9,360
North Custer Co. CD Pumpkin Creek Waterspreader	1,890		2,835	1,417	1,418
TOTALS	11,722		25,793		20,001
Flood	8,517		20,896		17,508
Waterspreader	3,205		4,897		2,494

TABLE B-17

IRRIGATION DEPLETIONS

Bighorn River below St. Xavier

Crop Requirement: 1.62 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)		Return Flow (acre-feet)	Depletion (acre-feet)
Big Horn Co. CD						
Pivot	3,129	5,069	2.09	6,559	1,415	5,144
Sideroll	4,717	7,642	2.09	9,858	2,106	7,752
Flood	1,329	2,153	2.85	3,788	981	2,807
TOTALS	9,175			20,205		15,703

Acres are below gauge at St. Xavier, so were depleted from river system at Miles City.

TABLE B-18

IRRIGATION DEPLETIONS

Yellowstone River between Billings and Miles City

Crop Requirement: 1.62 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)		Return Flow (acre-feet)	Depletion (acre-feet)
Yellowstone Co. CD						
Pivot	6,614	10,715	2.23	14,749	3,832	10,916
Sideroll	3,380	5,476	2.23	7,537	1,958	5,579
Flood	2,218	3,593	3.38	6,831	1,943	4,888
Treasure Co. CD						
Pivot	4,337	7,026	2.39	10,366	3,173	7,193
Sideroll	920	1,490	2.39	2,199	673	1,526
Flood	1,778	2,880	3.26	5,796	1,749	4,047
Northern tributaries	6,105	8,852	3.27	19,963	6,666	13,297
Rosebud Co. CD						
Pivot	26,870	43,529	2.39	64,219	19,655	44,564
Sideroll	2,495	4,042	2.39	5,963	1,825	4,138
Flood	5,160	8,359	3.76	16,821	5,077	11,744
North Custer Co. CD						
Pivot	3,968	6,428	2.18	8,650	2,110	6,539
Sideroll	50	81	2.18	109	25	84
Flood	243	394	3.27	795	241	554
Department of State Lands						
9931-r						
Flood	1,795	2,908	3.0	5,385	1,486	3,899
9933-r						
Flood	1,061	1,719	3.1	3,293	944	2,349
0034-r						
Waterspreader	2,271	1,658	1.46	3,317	1,658	1,659
U.S. Bureau of Land Management						
12334-02						
Sprinkler	418	677	2.0	836	170	666
TOTALS	69,683			176,829		123,642
Waterspreader	2,271			3,317		1,659
Flood	67,412			173,512		121,983

TABLE B-19

IRRIGATION DEPLETIONS

Powder River above Locate

Crop Requirement: 1.39 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)		Return Flow (acre-feet)	Depletion (acre-feet)
North Custer Co. CD						
Mainstem water spreading	2,585	1,935	1.5	3,877	1,939	1,939
Mizpah Creek tributaries	1,890	1,418	1.5	2,835	1,418	1,418
Sunday Creek	420	315	1.5	630	315	315
Powder River Co. CD						
Mainstem water spreading	4,120	3,090	1.5	6,180	3,090	3,090
Trib. water spreading	3,750	2,813	1.5	5,625	2,813	2,813
Prairie Co. CD						
Waterspreading	295	222	1.5	443	222	222
Department of State Lands 9934-r						
Waterspreader	2,734	1,994	1.46	3,988	1,994	1,994
TOTALS	15,794			23,578		11,791
Waterspreader	11,594			17,278		8,640
Flood	4,200			6,300		3,151

TABLE B-20

IRRIGATION DEPLETIONS

Yellowstone River between Miles City and Sidney

Crop Requirement: 0.89 acre-feet/acre

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
North Custer Co. CD					
Pivot	1,212	1,078	2,642	1,485	1,156
Sideroll	300	267	654	367	286
Flood	1,667	1,483	5,451	2,380	3,071
Prairie Co. CD					
Pivot	312	278	702	403	299
Sideroll					
Flood	21,929	19,516	67,322	28,683	38,639
Dawson Co. CD					
Pivot	11,025	9,812	24,806	14,244	10,562
Sideroll	920	818	2,070	1,189	881
Flood	6,182	5,502	18,979	8,086	10,893
Richland Co. CD					
Pivot	16,415	14,609	32,830	17,302	5,520
Sideroll	2,240	1,994	4,480	2,362	2,118
Flood	3,055	2,719	8,310	3,355	4,955
Little Beaver CD Tribs.					
Flood	2,654	2,362	4,273	1,146	3,126
Waterspreader	4,000	3,000	6,000	3,000	3,000
Stock ponds			1,800		1,800
Recreation ponds			700		700
Buffalo Rapids Project					
Terry Unit add	1,300	1,157	5,031	3,224	2,707
Fallon Unit add	800	712	3,096	1,430	1,666
Buffalo Rapids	1,000	890	3,780	1,734	2,046

TABLE B-20 (continued)

Location and Type of Irrigation	Acreage	Crop Irrigation (acre-feet)	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
Department of State Lands					
9931-r Flood	917	816	2,751	1,161	1,590
9933-r Flood	2,522	2,245	7,807	3,337	4,470
9934-r Water-spreader	4,937	3,641	7,281	3,639	3,641
U.S. Bureau of Land Management					
Waterspreader	1,992	1,462	2,924	1,462	1,462
Flood	8,320	7,405	16,640	5,541	11,099
TOTALS	93,699		230,329		126,290
Flood			211,624		115,687
Waterspreader			16,205		8,103
Stockpond			2,500		2,500

TABLE B-21

MONTHLY DISTRIBUTION OF DEPLETIONS FROM IRRIGATION RESERVATIONS
(percentage)

	Flood Irrigation Bighorn Basin	Flood Irrigation Tongue-Powder Basins	Flood Irrigation Stillwater-Clarks Fork Basins	Flood Irrigation Yellowstone Mainstem	All Water Spreaders
January	- 3	- 3	- 2	- 2	0
February	- 2	- 2	- 1	- 2	0
March	- 3	- 2	- 1	- 2	0
April	- 4	- 3	6	- 1	50
May	6	18	17	13	50
June	27	17	17	16	0
July	40	37	30	36	0
August	38	33	25	31	0
September	18	17	11	19	0
October	- 7	- 5	5	- 1	0
November	- 6	- 4	- 4	- 4	0
December	- 4	- 3	- 3	- 3	0
TOTAL	100	100	100	100	100

Note: Negative values indicate months when the return flow is greater than the depletion.

TABLE B-22

MONTHLY DISTRIBUTION OF NON-IRRIGATION DEPLETIONS
(percentage)

	Municipal	Industrial	Energy	Livestock
January	3	1	8	0
February	3	1	7	0
March	6	2	8	0
April	7	6	8	0
May	10	19	9	50
June	10	24	9	50
July	21	28	10	0
August	14	10	10	0
September	9	5	7	0
October	9	2	8	0
November	4	1	8	0
December	4	1	8	0
TOTAL	100	100	100	100

TABLE B-23

INSTREAM FLOW RESERVATIONS

(acre-feet)

	Yellowstone River			
	Livingston	Billings[2]	Miles City	Sidney
January	81,760	152,700	235,400	229,831
February	73,292	138,900	221,995	240,281
March	82,989	177,300	390,929	416,711
April	148,132	213,000	347,957	405,031
May	180,454	469,300	754,904	735,528
June[1]	507,853	1,125,000	1,557,980	1,495,644
July	232,013	370,400	631,856	647,090
August	120,220	215,205	237,415	164,166
September	92,508	184,900	266,682	194,917
October	144,463	219,700	359,578	369,377
November	106,488	207,000	327,730	347,920
December	91,596	171,466	246,466	245,814
Annual	1,861,768	3,644,871	5,578,892	5,492,310

[1]In the case of Livingston and Billings, the June total includes one-half of the dominant discharge.

[2]Billings instream flow reflect the board's change made November 1980.

TABLE B-23 (continued)

INSTREAM FLOW RESERVATIONS

(acre-feet)

	Stillwater River Absarokee	Clarks Fork River Edgar	Bighorn River St. Xavier	Tongue River at mouth	Powder River Locate
January	12,294	15,400	202,863	4,611	1,961
February	11,382	13,900	177,679	4,611	3,986
March	12,909	15,400	245,895	4,611	17,888
April	13,385	20,890	214,167	4,611	20,643
May	34,425	62,200	233,600	4,611	26,064
June	123,447	200,700	309,352	4,611	10,946
July	63,318	94,480	220,512	4,611	4,303
August	29,507	26,960	172,127	4,611	891
September	28,555	23,800	154,676	4,611	527
October	23,360	20,500	165,979	4,611	579
November	13,385	21,400	184,421	4,611	3,664
December	13,831	17,060	196,716	4,611	3,749
Annual	379,798	532,690	2,477,987	55,332	95,201

The irrigation depletions were based on information from a number of U.S. Bureau of Reclamation (BOR) Definite Plan Reports for different areas throughout the Yellowstone Basin. Depletions for each area are based on temperature, precipitation, evaporation, cropping types, and irrigation methods.

Crop requirements were calculated by the U.S. Bureau of Reclamation using the Jensen and Haise method. This method is based on an energy budget approach and relies on the principle that consumptive plant use per unit area is controlled by the amount of energy available to evapotranspire the water, rather than the amount used by the crop itself. The crop requirement values are average annual figures based on 30 to 40 years of temperature, solar radiation, and precipitation data for different areas in the basin.

In order to determine depletions from the surface water supply, the following values were used to calculate return flows (the net return flow is the difference between the diversionary requirement and crop irrigation requirement; the return flow is a percentage of the net return flow): 95 percent for sprinkler (center pivot) irrigation, 60 percent for flood irrigation, and 50 percent for waterspreaders. The difference between return flow and net return flow is that volume of water lost to deep percolation and not returned to the source of supply. This volume, therefore, is included as part of the total depletion.

Following is an example of the calculation for irrigation depletions using the above method:

Park County Conservation District sprinkler irrigation of 1,369 acres:

1. Crop irrigation requirement = irrigated acres x crop requirements
   = 1,369 x 1.33
   = 1,820.8 acre-feet

2. Net return flow = diversion - crop irrigation requirement
   = 2,738 - 1,820.8
   = 917.2 acre-feet

3. Return flow = 95 percent of net return flow
   = 0.95 x 917.2
   = 871.4 acre-feet

4. Depletion = crop irrigation requirement + (net return flow - return flow)
   = 1,820.8 + (917.2 - 871.4)
   = 1,867 acre-feet

The total depletions calculated in Tables B-12 through B-20 were broken down into monthly values for use in Opstudy. Diversions, based on conveyance and on farm efficiencies (from BOR Definite Plan Reports), also are found in Tables B-12 through B-20. The monthly conversion factors for each subbasin, based on BOR Definite Plan Reports, are presented in Table B-21.

Instream Flow Reservations

In its order, the board gave instream flow reservations second highest priority upstream from Billings and third highest priority below Billings. Instream reservations, intended to protect fish, wildlife, and public health, require that water remain in the river except when reservations with higher priority, or senior appropriations, cannot be met.

The instream flow reservations were made on a monthly basis and were used directly in the operation study. Table B-23 shows the instream flow reservations. The acre-foot volumes for the months which were split by the board's order were totalled to obtain monthly volumes. Two of the instream flow allotments (Livingston and Billings) included a dominant discharge value--that is, a minimum 24-hour flow volume. To account for this, one-half of that volume was added to the instream flow for June, the month of highest runoff.

Multiple Use/Storage Reservations

Four reservations for multiple use storage facilities are incorporated into the Yellowstone River Opstudy. These reservations have the lowest priority; in other words, all senior water rights and all other water reservations must be satisfied before water can be stored in these facilities.

The first reservation was for increased storage at the existing Tongue River Reservoir. The Board of Natural Resources and Conservation granted an increase in the reservoir's storage capacity from 68,000 acre-feet to 383,000 acre-feet. The enlarged reservoir was assumed to have a 130,000 acre-foot capacity in the model. This capacity is the latest preferred option for that site.

The other water storage reservations were for three proposed offstream storage reservoirs between Billings and Miles City. The BOR has determined the following storage capacities for these reservoirs:

Cedar Ridge - 121,800 acre-feet
Buffalo Creek - 68,700 acre-feet
Sunday Creek - 539,000 acre-feet

The releases from these reservoirs were assumed to provide a firm yield of up to 235,000 acre-feet per year for industrial and irrigation use.

FUTURE WATER FOR WYOMING

Because Wyoming's share of water from the tributaries of the Yellowstone (under the terms of the Yellowstone River Compact) has yet to be quantified, future depletions for Wyoming were estimated by the Missouri River Basin States Association. The projected depletions can be found in its 1978 report, Yellowstone Basin and Adjacent Coal Area - Level B Study (MRBC 1978a, MRBC 1978b). Depletions used in the Opstudy for the Powder and Tongue river basins are from the association's Yellowstone Level B Year 2000 Recommended Development Plan (MRBC 1978a, MRBC 1978b). Wyoming depletions for the Bighorn Basin, which are used in the Yellowstone model to generate the flows for the Bighorn River at St. Xavier, are also from the Level B Year 2000 plan.

The depletions for these basins can be found in Tables B-24, B-25, and B-26. Monthly distributions for each specific use can be found in Tables B-21 and B-22. These distributions are the same as those for Montana depletions.

In addition to the depletions in Tables B-25 and B-26, 12,000 acre-feet of water was depleted for irrigation purposes on the Clarks Fork of the Yellowstone River in Wyoming, as estimated in the Level B Year 2000 plan.

RESERVED INDIAN WATER RIGHTS

The actual water rights of the Indian tribes in the Yellowstone River Basin will be determined by the courts or through negotiation. For this study, the amount of water depleted for use on the Indian reservations was based on the Yellowstone Level B Year 2000 plan. The depletions are shown in Table B-27. The water depleted for the Crow Indian Reservation in the Bighorn River Basin was assumed to be for irrigation. The water depleted for the Northern Cheyenne Reservation in the Tongue River Basin was assumed to be for energy development.

U.S. BUREAU OF RECLAMATION MUNICIPAL AND INDUSTRIAL WATER USE

The Bureau of Reclamation (BOR) has claimed the rights to sell water from its storage reservoirs in the Bighorn River Basin. The sales of 57,400 acre-feet per year from Boysen Reservoir on the Wind River and 300,000 acre-feet per year from Yellowtail Reservoir on the Bighorn River are accounted for in the BOR's Bighorn River Operations Study model. The sale of this water, therefore, is taken into account in the output from the Bighorn Opstudy, which is used as input to the Yellowstone Opstudy at the St. Xavier station on the Bighorn River.

TABLE B-24

BIGHORN RIVER BASIN

Depletions for Wyoming under Level B Year 2000 Recommended Plan

Wind River

	Acre-feet/Year
Irrigation	62,000
Municipal	708
Livestock	1,580
Industry	2,080

Bighorn River (Boysen to Kane)

	Acre-feet/Year
Irrigation	82,500
Municipal	1,150
Livestock	1,900

Shoshone River

	Acre-feet/Year
Irrigation	93,100
Municipal	1,200
Livestock	2,554
Industry	7,580

TABLE B-25

TONGUE RIVER BASIN

Depletions for Wyoming under Level B Year 2000 Recommended Plan

Tongue River above state line

	Acre-feet/Year
Irrigation	15,920
Municipal	200
Livestock	1,300
Energy	30,311

TABLE B-26

POWDER RIVER BASIN

Depletions for Wyoming under Level B Year 2000 Recommended Plan

Powder River Basin above Arvada

	Acre-feet/Year
Irrigation	19,700
Municipal	3,000
Livestock	900

Arvada to state line

	Acre-feet/Year
Irrigation	10,900
Municipal	525
Livestock	900
Energy	42,220

Little Powder

	Acre-feet/Year
Irrigation	2,500
Livestock	300

TABLE B-27

RESERVED INDIAN WATER
(af = acre-feet)

CROW INDIAN NATION

	Acres	Diversion	Depletion
Little Bighorn	24,900	78,200 af	40,700 af
Hardin Unit	42,000	131,700 af	68,500 af
25% increase	16,700	52,400 af	27,200 af
	83,600	262,300 af	136,400 af*

*This depletion for irrigation is on the Bighorn River below St. Xavier and is subtracted from the flow at the Miles City gauging station.

NORTHERN CHEYENNE NATION

Energy 39,100 acre-feet**

**This depletion is subtracted from the flows of the Tongue River at Miles City.

MONTANA WATER RIGHTS GRANTED IN THE YELLOWSTONE RIVER BASIN SINCE 1975

The 1975 level of development flows used in the Opstudy model reflect all of the depletions from water rights granted in Montana prior to 1975. Considerable effort is required to update these flows to a later level of development (1980, for example). Therefore, they have not been updated by the U.S. Bureau of Reclamation. In lieu of using more current level of development flows, all of the Montana provisional water rights permits issued since 1975 were used in the Yellowstone Opstudy model. These depletions were subtracted from the 1975 level of development flows at the proper location, along with the depletions from the reservations, in order to determine water availability.

Water rights granted since 1975 were totalled according to use for each node in the Opstudy model. Depletions were calculated using the same methods used to calculate depletions for the reservations. These depletions, along with diversion and return flows for each use, are shown in Table B-28.

UTAH INTERNATIONAL (FENCE CREEK) PROJECT - POWDER RIVER BASIN

Utah International Inc. has designed a project to divert water from the Powder River and Fence Creek, a tributary of the Powder River, to an offstream storage reservoir near the Montana-Wyoming border. The water rights associated with this project, assuming they are granted, will be junior to the reservations.

The reservoir will have a maximum capacity of 106,700 acre-feet and is expected to provide up to 40,290 acre-feet per year for energy, irrigation, and municipal uses. The diversion, depletions, and return flows for each use are presented in Table B-29.

TABLE B-28

MONTANA WATER RIGHTS GRANTED IN THE YELLOWSTONE RIVER BASIN SINCE 1975

Basin	Use	Diversion (acre-feet)	Return Flow (acre-feet)	Depletion (acre-feet)
Yellowstone River above Livingston	Flood Irrigation	10,231	3,683	6,548
	Sprinkler Irrigation	155	50	105
	Municipal	40	25	15
	Livestock	71	0	71
	Industrial	967	0	967
Stillwater River	Flood Irrigation	148	41	107
	Sprinkler Irrigation	19	2	17
	Livestock	3	0	3
	Municipal	267	187	80
Clarks Fork of the Yellowstone River	Flood Irrigation	40,788	8,158	32,630
	Sprinkler Irrigation	170	15	155
	Municipal	68	43	25
	Livestock	436	0	436
Yellowstone River Livingston-Billings	Flood Irrigation	4,183	1,339	2,844
	Sprinkler Irrigation	603	193	410
	Municipal	1	1	0
	Livestock	25	0	25
	Industrial	120	0	120
Tongue River	Flood Irrigation	2,862	458	2,404
	Sprinkler Irrigation	870	139	731
	Municipal	750	473	277
	Livestock	290	0	290
Yellowstone River Billings-Miles City	Flood Irrigation	30,149	8,743	21,406
	Sprinkler Irrigation	1,460	438	1,022
	Municipal	3,934	2,478	1,456
	Livestock	443	0	443
Powder River	Flood Irrigation	27,336	13,668	13,668
	Sprinkler Irrigation	222	111	111
	Livestock	421	0	421
Yellowstone River Miles City-Sidney	Flood Irrigation	46,903	19,231	27,672
	Sprinkler Irrigation	1,773	1,253	520
	Municipal	1,034	651	383
	Livestock	550	0	550
Bighorn River Below St. Xavier	Flood Irrigation	1,369	356	1,013
	Livestock	24	0	24

TABLE B-29

DEPLETIONS FROM POWDER RIVER BASIN FOR UTAH INTERNATIONAL (Fence Creek) PROJECT

(acre-feet)

Use	Diversion	Return Flow	Depletion
Irrigation	7,610	3,805	3,805
Energy	30,000	0	30,000
Municipal	2,680	1,688	992

APPENDIX C

WATER AVAILABILITY IN THE YELLOWSTONE RIVER BASIN UNDER "PRESENT" CONDITIONS

INTRODUCTION

The excess flows available for appropriation, calculated in Tables 2 through 10 (pages 13-21), include the depletions associated with all of the reservations, Indian reserved water rights, and rights allocated to Wyoming under the Yellowstone River Compact that have yet to be developed or quantified. Therefore, the excess flows do not represent the amount of water available for appropriation at the present time. The undeveloped rights and reservations will be completed and eventually put to use, although this may not occur in the near future. Additional water should be available until the reservations are fully developed and all of the Indian and Wyoming rights have been quantified and developed. This water would be available for use in Montana and could be put to beneficial use by granting temporary or provisional permits for its appropriation.

Water availability under present conditions is discussed in this appendix. For purposes of this discussion, it was assumed that only half of the water reserved for irrigation and none of the water reserved for offstream storage was as yet being used. Also, estimated future depletions for the Wyoming portion of the Yellowstone River Basin and Indian tribes existing in the basin were not taken into account.

METHODS

The DNRC Yellowstone River Opstudy model was used to determine the amount of excess water available for development at the present time. In determining this amount, the depletions used to generate the excess flows in the main report were decreased as follows:

(1) Only 50 percent of the irrigation reservations will be developed in the near future.
(2) The U.S. Bureau of Reclamation reservations for offstream storage will not be developed in the near future.
(3) The estimated Indian reserved water rights for the Northern Cheyenne (Tongue River Basin), Crow (Bighorn River Basin), and Wind River (Bighorn River Basin) tribes were not accounted for.
(4) None of the estimated future depletions for Wyoming (from the Missouri River Basin States Association's Level B Year 2000 study) in the Bighorn, Tongue, Powder, and Clarks Fork drainages were accounted for.
(5) The depletions associated with the Utah International Fence Creek Project on the Powder River were not accounted for.

The decrease in depletions used to estimate water availability under "present conditions," and the depletions used to calculate excess flow under "future conditions" (including all water reservations, Indian reserved water rights, Wyoming rights,

etc.), are listed in Table C-1. The provisional permits granted by DNRC in the Yellowstone Basin since 1975 are included in the totals for both "present" and "future" conditions.

To estimate water availability under "present" conditions, the model was operated in the same way it was when estimating water availability for the future, except for the following changes:

(1) None of the reservoirs designed to regulate flows for the future estimated depletions in the Wyoming portion of the Powder River Basin were operative; thus, they were not included.
(2) The proposed Fence Creek Reservoir and diversion in the Powder River Basin were not included in the model.
(3) None of the reservoirs designed to regulate flows for the estimated future depletions in the Wyoming portion of the Tongue River Basin were operative; thus, they were not included.
(4) The Tongue River Dam was operated according to current operating criteria and current reservoir specifications (storage capacity of 68,000 acre-feet).
(5) None of the offstream storage reservoirs proposed by the U.S. Bureau of Reclamation were included in the model.

The 1975 level of development flows were used as the major input to estimate "present" water availability at all nodes in the model, except for the node on the Bighorn River near St. Xavier, Montana. As mentioned in the main report, flows in the Bighorn Basin at St. Xavier were generated from the U.S. Bureau of Reclamation's Bighorn River Opstudy model. Flows at St. Xavier were, thus, handled as external input to the DNRC Yellowstone Opstudy model. In the version of the Yellowstone Opstudy used to predict "future" water availability in the Bighorn basin, the depletions used as input to the model were estimated from the Missouri River Basin States Association's Level B Year 2000 Recommended Development Plan. In order to determine "present" water availability in the Bighorn River Basin, the 1985 "without plan" depletions were used in the Bureau of Reclamation's Bighorn Opstudy to generate the flows at St. Xavier. "Without plan" depletions represent the conditions likely to occur in the absence of a plan and, therefore, reflect the activities of the private sector, with only the help of ongoing programs from the state and federal agencies. The Wyoming depletions for the 1985 "without plan" development level in the Wyoming portion of the Bighorn River Basin were as follows:

TABLE C-1

DEPLETIONS USED IN YELLOWSTONE OPSTUDY MODEL FOR "FUTURE" AND "PRESENT" CONDITIONS
(acre-feet/year)

USE	LOCATION	"FUTURE" CONDITIONS	"PRESENT" CONDITIONS
Irrigation-Waterspreader	Yellowstone: Livingston to Billings	198	198
	Clarks Fork above Edgar	5,000	0
	Yellowstone: Billings to Miles City	1,660	830
	Bighorn River below St. Xavier	136,400	0
	Tongue River (MT)	2,404	1,202
	Yellowstone: Miles City to Sidney	10,600	6,549
	Powder River (MT)	8,640	4,320
Flood Irrigation	Yellowstone above Livingston	42,175	24,414
	Yellowstone: Livingston to Billings	87,333	45,194
	Stillwater above Absarokee	8,494	4,309
	Clarks Fork above Edgar	39,868	36,326
	Yellowstone: Billings to Miles City	131,114	76,771
	Bighorn River below St. Xavier	16,716	8,864
	Tongue River (WY)	15,920	0
	Tongue River (MT)	20,643	11,889
	Yellowstone: Miles City to Sidney	143,277	85,735
	Powder River (WY)	19,700	0
	Little Powder River (WY)	10,900	0
	Powder River (MT)	19,429	17,854
Energy	Yellowstone: Livingston to Billings	120	120
	Tongue River (WY)	30,311	0
	Tongue River (MT)	39,100	0
	Little Powder River (WY)	42,220	0
Municipal	Yellowstone above Livingston	1,670	1,670
	Yellowstone: Livingston to Billings	22,903	22,903
	Stillwater above Absarokee	99	99
	Clarks Fork above Edgar	25	25

TABLE C-1 (continued)

USE	LOCATION	"FUTURE" CONDITIONS	"PRESENT" CONDITIONS
Municipal	Yellowstone: Billings to Miles City	2,530	2,530
	Tongue River (MT)	278	278
	Yellowstone: Miles City to Sidney	1,601	1,601
	Powder River (MT)	225	225
Rural-Domestic	Tongue River (WY)	200	0
	Powder River (WY)	3,000	0
Industrial	Yellowstone above Livingston	967	967
Livestock	Yellowstone above Livingston	71	71
	Yellowstone: Livingston to Billings	25	25
	Clarks Fork above Edgar	436	436
	Yellowstone: Billings to Miles City	443	443
	Bighorn River below St. Xavier	24	24
	Tongue River (WY)	1,200	0
	Tongue River (MT)	290	290
	Yellowstone: Miles City to Sidney	550	550
	Powder River (WY)	900	0
	Powder River (MT)	721	721
Offstream Storage	Yellowstone: Billings to Miles City	161,000	0
	Powder River (Fence Creek):		
	Irrigation	3,805	0
	Energy	30,000	0
	Municipal	950	0
TOTAL		1,066,135	357,433

LOCATION	USE	DEPLETION (acre-feet/year)
Wind River	Irrigation	1,200
	Municipal	200
	Livestock	200
	Industry	200
Bighorn River	Irrigation	6,800
	Municipal	300
	Livestock	400
Shoshone River	Irrigation	2,400
	Municipal	300
	Livestock	200
	Industry	300

The flows computed for the Bighorn River at St. Xavier, using the depletions presented above, are shown in Table C-2.

Other than the depletion changes, changes in reservoir operations, and input flows at St. Xavier, there were no differences in the operation of Opstudy as used to estimate "present" versus "future" water availability. All of the restraints applying to the previous run, such as reservation priorities, were applicable to the model version used to estimate "present" conditions.

RESULTS

The amount of water available for appropriation in the basin under "present" conditions is presented in Tables C-3 through C-11. A table is presented for each mainstem or tributary node in the Opstudy model. These flows include the water available in Tables 2 through 10 in the main text and the incremental excess flows associated with the decrease in depletions for water reservations, Indian reserved water rights, and Wyoming water for the "present" conditions Opstudy run. The excess flows represent the portion of the streamflow that is available on a temporary basis--until all of the reservations, Indian water rights, and Wyoming water rights have been developed.

The results indicate that, under "present" conditions, no water is available in the basin in eight out of ten years during most of the irrigation season. However, provisional water from the mainstem, but not the tributaries, is available during the irrigation season in six out of ten years. This water was not available under the "future" conditions scenario and may indicate the possibility for some increase in irrigation withdrawals directly from the mainstem.

TABLE C-2

1985 "WITHOUT DEVELOPMENT" LEVEL FLOWS: BIGHORN RIVER AT ST. XAVIER, MONTANA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1939	173.1	172.8	174.1	127.9	113.7	113.5	112.6	124.2	131.9	164.2	166.6	170.4	1743.9
1940	125.1	125.0	133.3	137.1	67.3	120.2	62.7	81.2	122.8	164.5	138.3	137.8	1415.3
1941	100.8	105.0	138.0	141.2	126.4	118.0	116.7	184.6	188.9	194.4	193.6	192.7	1800.3
1942	288.5	288.3	288.5	189.3	194.6	229.5	253.2	170.1	173.7	178.8	177.8	176.8	2609.2
1943	239.1	238.9	239.1	243.7	251.6	299.4	627.9	181.9	185.4	190.6	189.6	188.6	3075.7
1944	265.1	264.9	265.1	265.0	274.0	327.0	411.7	163.0	166.5	171.7	170.6	169.6	2854.3
1945	213.9	213.7	213.9	128.2	112.2	122.7	484.1	222.8	226.3	231.5	230.4	229.4	2629.0
1946	252.1	251.9	252.1	127.6	111.1	110.7	124.1	192.9	196.5	201.6	200.6	199.5	2220.7
1947	241.5	241.3	241.5	271.4	280.7	334.6	628.1	211.6	215.0	220.2	219.2	218.2	3323.3
1948	290.2	290.0	290.2	151.7	155.0	181.2	218.3	167.9	171.4	176.5	175.5	174.4	2442.4
1949	220.5	220.2	220.4	128.7	121.4	140.3	187.0	177.4	180.9	186.1	185.2	184.2	2152.3
1950	244.4	244.1	244.4	127.4	110.4	110.2	368.3	226.5	230.1	235.3	234.3	233.3	2608.7
1951	286.3	286.0	286.3	146.4	149.5	174.5	547.8	231.8	235.2	240.3	239.3	238.2	3061.5
1952	274.5	274.2	274.5	177.7	182.3	214.4	199.1	163.0	166.5	171.6	170.6	169.6	2438.1
1953	203.7	203.4	203.7	127.9	114.1	113.3	123.3	127.6	131.5	152.9	144.4	120.6	1766.3
1954	202.4	202.1	202.3	128.0	111.9	111.5	102.8	138.3	142.2	150.5	145.1	144.1	1781.1
1955	172.8	172.5	172.8	127.9	113.2	112.5	106.6	116.9	123.8	153.6	145.3	121.6	1639.7
1956	199.4	199.2	199.4	194.8	200.3	236.6	229.8	155.9	159.4	164.6	163.6	162.5	2265.6
1957	217.3	217.0	217.3	292.8	303.3	363.0	415.5	204.0	207.6	212.8	211.9	210.9	3073.4
1958	231.6	231.4	231.6	129.3	112.2	110.6	101.2	152.4	156.1	161.4	160.5	159.5	1937.8
1959	199.0	198.7	199.0	128.5	114.2	112.7	136.5	137.9	141.9	151.4	144.3	143.3	1807.2
1960	200.8	200.5	200.8	126.9	114.8	116.1	108.4	94.4	138.3	133.9	159.6	144.5	1739.0
1961	97.5	118.1	97.9	56.9	76.6	89.3	28.1	80.9	143.1	172.3	193.0	163.6	1317.4
1962	134.0	132.2	133.9	182.9	187.8	221.5	331.4	182.0	185.5	190.6	189.6	188.5	2260.1
1963	229.5	229.3	229.5	201.5	207.4	245.8	255.7	191.6	195.2	200.3	199.3	198.3	2583.5
1964	230.9	230.6	230.9	206.7	212.8	252.3	400.2	175.1	178.6	183.7	182.7	181.6	2665.9
1965	239.8	239.5	239.8	315.5	327.1	392.0	639.4	233.9	237.3	242.4	241.3	240.2	3588.2
1966	219.9	219.7	219.9	127.0	114.5	116.1	70.7	91.2	130.2	153.1	186.7	182.4	1831.2
1967	134.3	133.4	136.9	250.8	259.2	310.2	744.1	202.8	206.3	211.5	210.5	209.4	3009.4
1968	266.0	265.7	266.0	148.3	151.5	177.7	266.3	232.2	235.6	240.7	239.6	238.6	2728.2
1969	261.1	260.9	261.1	127.7	110.7	110.3	174.5	179.1	182.6	187.8	186.8	185.8	2228.5
1970	216.2	215.9	216.2	169.7	173.9	204.7	280.7	177.5	181.1	186.2	185.2	184.2	2391.4
1971	255.9	255.6	255.9	331.1	343.4	411.7	477.7	230.0	233.6	238.9	238.0	237.0	3508.9
1972	316.3	316.0	316.3	180.1	184.8	217.9	232.7	205.9	209.4	214.5	213.4	212.4	2819.7
1973	258.7	258.4	258.7	187.5	192.6	227.2	253.2	249.4	253.1	258.2	257.1	256.1	2910.2
1974	282.3	282.0	282.2	250.4	258.8	308.2	353.9	186.3	189.9	195.1	194.0	193.0	2976.1
1975	260.7	260.5	260.7	197.7	203.4	240.5	725.6	132.9	136.2	143.9	138.9	137.0	2838.0
AVERAGE	222.3	222.7	223.4	177.1	174.0	199.9	294.6	172.4	180.8	189.9	189.8	186.4	2433.6
MEDIAN	229.5	229.3	229.5	148.3	151.5	177.7	232.7	177.5	181.1	186.2	186.8	184.2	2438.1

TABLE C-3

PRESENT CONDITIONS

EXCESS FLOWS: YELLOWSTONE RIVER AT LIVINGSTON, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	1.8	0.0	0.0	0.0	0.0	4.0
February	2.9	0.0	0.0	0.0	0.0	4.6
March	2.5	0.0	0.0	0.0	0.0	4.7
April	5.0	0.0	0.0	0.0	0.0	0.0
May	143.7	0.0	38.8	145.5	203.4	244.2
June	266.1	0.0	99.8	204.7	327.3	547.1
July	251.8	12.1	190.7	233.8	310.2	394.7
August	76.0	0.0	15.1	54.9	90.9	159.6
September	38.7	0.0	11.3	26.5	42.7	79.7
October	5.2	0.0	0.0	0.0	0.0	2.8
November	6.4	0.0	0.0	0.0	0.0	12.1
December	3.3	0.0	0.0	0.0	0.0	6.6
Annual	803.3	137.6	562.4	818.2	1001.5	1342.2

TABLE C-4

PRESENT CONDITIONS

EXCESS FLOWS: STILLWATER RIVER AT ABSAROKEE, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	3.8	0.0	0.0	4.0	5.4	7.4
February	3.7	0.0	1.8	3.5	4.1	7.1
March	4.1	0.0	0.9	2.8	4.6	6.7
April	9.1	0.0	0.0	5.0	11.9	16.0
May	44.9	0.0	32.8	39.8	61.8	83.0
June	83.0	0.0	56.0	84.8	112.1	150.2
July	90.3	12.1	66.4	88.1	104.4	140.6
August	22.8	0.0	13.6	20.1	31.9	43.5
September	10.7	0.0	3.8	9.7	13.9	19.5
October	8.5	0.0	5.8	8.4	9.7	15.5
November	8.9	0.0	9.3	11.7	12.4	14.9
December	5.5	0.0	5.3	6.8	7.5	9.0
Annual	295.5	110.0	249.8	302.5	367.8	418.9

TABLE C-5

PRESENT CONDITIONS

EXCESS FLOWS: CLARKS FORK AT EDGAR, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	5.9	0.0	0.0	6.8	8.7	11.5
February	6.1	0.0	3.5	5.8	8.3	10.4
March	6.3	0.0	0.9	7.0	8.2	10.7
April	8.0	0.0	0.0	0.0	5.5	15.4
May	42.7	0.0	30.1	38.0	48.5	83.9
June	56.1	0.0	0.0	34.2	61.4	133.8
July	46.3	0.0	0.6	24.7	38.7	84.5
August	11.4	0.0	0.0	0.0	7.0	26.5
September	8.6	0.0	0.0	0.8	7.9	18.2
October	11.4	0.0	7.8	10.8	13.0	20.1
November	9.2	0.0	8.8	10.7	12.3	16.1
December	8.2	0.0	8.2	10.3	11.1	12.8
Annual	220.0	96.6	141.2	205.1	229.6	386.6

TABLE C-6

PRESENT CONDITIONS

EXCESS FLOWS: YELLOWSTONE RIVER AT BILLINGS, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	13.6	0.0	0.0	9.3	11.5	29.3
February	25.3	0.0	3.5	13.0	20.8	50.4
March	23.0	0.0	0.9	9.4	18.9	37.2
April	47.4	0.0	0.0	5.0	54.6	90.5
May	196.9	0.0	77.5	201.7	232.4	370.3
June	378.7	0.0	175.5	263.4	505.6	820.2
July	471.9	12.1	262.8	416.0	577.9	800.9
August	95.7	0.0	15.1	54.9	96.0	206.5
September	61.7	0.0	11.3	36.9	72.2	111.5
October	45.0	0.0	9.8	26.2	40.3	85.8
November	27.5	0.0	11.0	22.0	32.3	51.9
December	18.0	0.0	8.2	17.5	22.4	31.5
Annual	1404.5	362.2	1209.4	1335.2	1666.1	2437.3

TABLE C-7

PRESENT CONDITIONS

EXCESS FLOWS: TONGUE RIVER AT MILES CITY, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	7.9	4.7	6.3	7.1	7.9	9.9
February	11.2	4.2	5.6	6.7	8.6	14.6
March	27.6	1.7	10.4	15.1	26.1	42.8
April	22.9	0.0	9.1	15.7	21.9	45.0
May	30.8	0.0	14.9	27.9	38.3	57.5
June	65.2	0.0	25.6	67.5	76.7	121.2
July	19.0	0.0	1.6	9.1	13.8	38.8
August	1.9	0.0	0.0	0.0	0.0	0.0
September	3.3	0.1	0.1	0.1	0.1	8.0
October	13.2	0.0	10.0	11.8	14.0	25.1
November	15.0	4.8	12.0	14.8	16.5	26.3
December	9.1	6.0	7.9	8.7	9.1	13.7
Annual	227.4	75.2	184.2	227.1	261.8	346.8

TABLE C-8

PRESENT CONDITIONS

EXCESS FLOWS: YELLOWSTONE RIVER AT MILES CITY, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	178.5	95.8	141.1	175.2	189.4	274.9
February	216.5	123.7	159.2	193.3	235.6	280.7
March	186.5	32.2	146.8	161.1	211.4	298.5
April	164.1	0.0	103.5	151.1	188.1	275.9
May	210.5	0.0	94.1	203.4	244.6	417.2
June	397.5	0.0	175.5	263.4	505.6	840.7
July	595.5	12.1	262.8	460.5	770.2	1007.2
August	216.4	57.2	146.7	194.9	225.5	360.3
September	153.5	15.6	108.8	150.9	181.1	232.8
October	142.6	30.8	102.1	117.7	163.0	251.0
November	147.7	71.7	123.5	126.7	163.1	233.2
December	153.2	88.1	114.4	154.2	162.5	219.2
Annual	2762.2	1031.4	2592.9	2885.7	3122.4	4208.2

TABLE C-9

PRESENT CONDITIONS

EXCESS FLOWS: POWDER RIVER AT LOCATE, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	6.2	3.1	5.0	5.2	6.0	9.0
February	23.3	0.5	5.6	7.2	9.9	28.7
March	66.3	0.5	19.7	37.3	43.5	135.1
April	24.2	0.0	3.9	9.9	19.6	46.8
May	28.0	0.0	0.0	11.6	27.5	45.7
June	84.4	0.0	26.3	59.3	93.2	140.1
July	23.5	0.0	2.2	11.4	22.4	41.8
August	6.4	0.0	0.0	0.3	4.6	10.5
September	6.5	0.0	0.0	0.0	0.4	10.9
October	13.2	2.8	6.8	8.0	13.0	18.0
November	8.2	1.8	5.4	8.0	10.3	15.8
December	5.5	2.5	3.6	4.6	5.0	6.9
Annual	295.8	108.7	198.0	264.3	296.4	478.5

TABLE C-10

PRESENT CONDITIONS

EXCESS FLOWS: BIGHORN RIVER AT ST. XAVIER, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	32.7	0.0	14.4	28.0	38.6	58.2
February	52.7	21.0	39.3	52.9	63.6	83.2
March	9.2	0.0	0.0	0.0	0.0	15.2
April	13.7	0.0	0.0	0.0	0.0	29.5
May	11.6	0.0	0.0	0.0	0.0	18.0
June	7.6	0.0	0.0	0.0	0.0	0.0
July	116.1	0.0	0.0	32.7	60.2	257.2
August	18.0	0.0	0.0	5.4	12.5	39.5
September	31.6	0.0	16.7	26.4	34.2	60.3
October	27.5	0.0	10.5	20.2	28.4	54.2
November	15.7	0.0	0.0	2.4	9.2	34.8
December	9.8	0.0	0.0	0.0	0.0	21.5
Annual	346.4	26.6	180.9	246.8	427.1	622.7

TABLE C-11

PRESENT CONDITIONS

EXCESS FLOWS: YELLOWSTONE RIVER AT SIDNEY, MONTANA
(thousand acre-feet)

	Mean	80th Percentile	60th Percentile	50th Percentile	40th Percentile	20th Percentile
January	197.6	96.5	178.3	194.6	214.6	296.3
February	233.8	113.6	171.0	199.5	237.3	322.2
March	329.8	33.6	237.0	279.8	337.5	505.5
April	215.7	2.1	81.2	182.6	219.5	333.5
May	208.8	0.0	88.1	140.7	249.8	298.8
June	529.1	0.0	237.2	358.7	794.9	1122.9
July	608.7	8.7	235.3	370.6	757.2	1023.7
August	229.9	35.3	181.6	212.2	230.3	380.6
September	181.8	15.6	110.9	186.7	217.0	275.3
October	152.9	9.7	96.4	119.4	173.4	258.0
November	146.5	47.8	122.0	138.5	166.3	221.8
December	159.6	75.4	111.2	139.7	198.3	255.9
Annual	3194.2	1106.4	2828.9	3384.4	3568.8	4950.2

Water available for appropriation on an annual basis is increased by approximately 100 percent at all locations on the mainstem under "present" conditions. This water is potentially available for offstream storage. However, the costs associated with constructing the projects to store this water may negate the use of these provisional flows because they would not be available after all reserved, Indian, and Wyoming water rights are developed.

As was the case when determining excess flows under "future" conditions, the major limiting factors in determining excess flows under "present" conditions are the instream flow reservations, which reserve a major portion of the streamflow in the basin. Therefore the reduced depletions under the "present" conditions do not result in proportionately greater flows available for appropriation.

APPENDIX D

WATER AVAILABLE FOR IRRIGATION

RESERVATIONS IN THE YELLOWSTONE RIVER BASIN

INTRODUCTION

Instream flow reservations have a higher priority than irrigation reservations above Billings. Thus, all or part of the irrigation reservations may not be available during a given irrigation season.

In contrast, irrigation reservations have a higher priority than instream flow reservations below Billings. It is possible, however, that future development on the Indian reservations and in the Wyoming portion of the Yellowstone River Basin (on the Tongue, Powder and Bighorn subbasins) could decrease the amount of water available for the irrigation reservations below Billings. A determination of the impacts such development could have on the amount of water available for the irrigation reservations in Montana is presented here.

METHODS

The Yellowstone River Operations Study Model (Opstudy) was used to estimate the frequency and magnitude of shortages associated with irrigation reservations. Two major changes in the model were made to calculate shortages associated with these reservations. First, to reflect the irrigation reservation priority date of December 15, 1978, only water rights granted from January 1, 1976 to December 14, 1978 were subtracted from the 1975 level flows. Previously, the depletions associated with water rights granted in the basin from 1976 to 1981 were subtracted from the 1975 level of development flows. Second, the water right application filed by Utah International, Inc. (UII) on the Powder River was taken into account. However, because the filing date for this project is considered to be junior to the reservations (because of the Yellowstone moratorium) depletions associated with the (UII) project were not considered when determining the amount of water available for the irrigation reservations.

The reservation priorities, as well as estimated future depletions for the Wyoming portions of the Clarks Fork, Tongue, Bighorn, and Powder River basins, were accounted for in the model. The future Wyoming depletions, along with the future Indian depletions used in the model, are presented in Tables B-24 through B-27 of this report and represent depletions for the year 2000. Because the resulting water availability calculations reflect the impacts of these depletions, the availability results represent conditions that may occur in the future; they do not necessarily represent conditions at the present time. However, the estimated completion dates for the projects associated with the irrigation reservations are generally set at or around the year 2000. Thus, the calculated water availability figures should approximate the conditions that will exist when the irrigation reservations are fully developed.

RESULTS

Yellowstone River above Billings

The amount of water available for the irrigation reservations above Billings is presented in Tables D-1 through D-5. Tables D-1 through D-4 show the results of water availability calculations for the Yellowstone River at Livingston, the Clarks Fork at Edgar, the Stillwater River near Absarokee, and the Yellowstone River at Billings. Table D-5 presents the water availability figures associated with the total irrigation reservations granted above Billings. As such, it summarizes the results presented in Tables D-1 through D-4.

The water availability results for the irrigation reservations below Billings are not presented in tabular form, but are summarized at the end of this section.

All results are presented on a percentile basis, comparing the monthly (or seasonal) irrigation reservation to the amount of water available for that reservation. For example, if enough water is available to completely satisfy the irrigation reservation for a given month, the value in the table is 100 percent.

Tables D-1 through D-5 show the amount of water available for the irrigation reservations on an average basis and at the 20th, 40th, 50th, 60th, 70th, 80th, and 90th percentiles for each month, as well as for the irrigation season as a whole. The results are based on the 1939-1975 period of record.

The percentile values can be interpreted in the following manner:

The value at a given percentile indicates the minimum amount of the irrigation reservation that can be met at the given frequency. For example, the 70th percentile value for the Yellowstone River at Livingston (Table D-1) for August is 52, which indicates that at least 52 percent of the reservation can be satisfied in seven out of 10 years, on the average.

This does not imply that only 52 percent of the water reserved for irrigation will be available during each of those seven years. Instead, it implies that only 52 percent of the reservation can be satisfied during one of the seven years; more water will probably be available during the other six years. The 60th percentile value for August indicates that at least 90 percent of the reservation can be satisfied in six out of 10 years. The 50th, 40th, and 20th percentiles all have values of 100, indicating that the reservation can be completely satisfied at all of these frequencies. Relating to the 70th percentile then, during an average 10-year period the reservations will be completely satisfied during five of those years, 90 percent of the reservation will be satisfied during one year, 52 percent will be

TABLE D-1

YELLOWSTONE RIVER AT LIVINGSTON:

PERCENTAGE OF IRRIGATION RESERVATIONS SATISFIED

(percentile)

	Average	20th	40th	50th	60th	70th	80th	90th
May	85	100	100	100	100	100	100	0
June	82	100	100	100	100	100	100	0
July	89	100	100	100	100	100	100	0
August	68	100	100	100	89	52	0	0
September	70	100	100	100	90	66	0	0
Irrigation Season	78	100	98	89	84	73	47	28

TABLE D-2

STILLWATER RIVER NEAR ABSAROKEE:

PERCENTAGE OF IRRIGATION RESERVATIONS SATISFIED

(percentile)

	Average	20th	40th	50th	60th	70th	80th	90th
April	100	100	100	100	100	100	100	0
May	86	100	100	100	100	100	100	0
June	79	100	100	100	100	100	100	0
July	88	100	100	100	100	100	100	0
August	67	100	100	100	90	52	0	0
September	67	100	100	100	78	0	0	0
October	75	100	100	100	100	100	100	0
Irrigation Season	79	100	96	90	85	77	57	25

TABLE D-3

CLARKS FORK OF THE YELLOWSTONE RIVER AT EDGAR:

PERCENTAGE OF IRRIGATION RESERVATIONS SATISFIED

		(percentile)						
	Average	20th	40th	50th	60th	70th	80th	90th
April	75	100	100	100	100	75	0	0
May	75	100	100	100	100	100	0	0
June	67	100	100	100	100	0	0	0
July	62	100	100	100	100	0	0	0
August	50	100	100	0	0	0	0	0
September	50	100	100	100	0	0	0	0
October	75	100	100	100	100	100	100	0
Irrigation Season	62	95	72	67	52	41	25	6

TABLE D-4

YELLOWSTONE RIVER FROM LIVINGSTON TO BILLINGS:

PERCENTAGE OF IRRIGATION RESERVATIONS SATISFIED

(percentile)

	Average	20th	40th	50th	60th	70th	80th	90th
May	83	100	100	100	100	100	100	0
June	82	100	100	100	100	100	100	0
July	89	100	100	100	100	100	100	0
August	68	100	100	100	90	52	0	0
September	70	100	100	100	90	66	0	0
Irrigation Season	79	100	98	89	84	73	47	28

TABLE D-5

YELLOWSTONE RIVER--ALL IRRIGATION RESERVATIONS ABOVE BILLINGS:

PERCENTAGE OF IRRIGATION RESERVATIONS SATISFIED

(percentile)

	Average	20th	40th	50th	60th	70th	80th	90th
April	89	100	100	100	100	89	56	56
May	83	100	100	100	100	100	93	0
June	81	100	100	100	100	94	94	0
July	88	100	100	100	100	96	96	0
August	67	100	100	96	77	50	0	0
September	69	100	100	100	86	61	0	0
October	75	100	100	100	100	100	100	0
Irrigation Season	77	99	96	88	82	72	47	27

satisfied in another year, and less than 52 percent will be available during the remaining three years.

Yellowstone River below Billings

Because irrigation reservations are senior to instream flow reservations below Billings, water to satisfy the irrigation reservation is available virtually all of the time. The major impact on water availability in this section of the Yellowstone River Basin will be the future depletions by Wyoming and the Indian tribes.

Because water availability for the irrigation reservations was generally 100 percent at all frequencies below Billings, only the averages and frequencies at which the reservations were not completely satisfied are presented.

Tongue River at Miles City:

	May	June	July	August	Sept.	Irr. Season
Average	100	100	97	97	97	98

Reservations are satisfied at all percentiles.

Powder River at Locate:

	April	May	June	July	August	Sept.	Irr. Season
Average	100	98	99	92	90	92	96
90th Percentile	100	100	100	100	90	40	90

Yellowstone River at Miles City:

Reservations are satisfied during the entire period of record.

Yellowstone River at Sidney:

	May	June	July	August	Sept.	Irr. Season
Average	100	100	100	97	99	99

Reservations are satisfied at all percentiles.

Bighorn River at St. Xavier:

Reservations are satisfied during the entire period of record.

CONCLUSIONS

Table D-5 shows the water available for all of the irrigation reservations above Billings and, therefore, best summarizes the pertinent information. From Table D-5 it is evident that significant shortages begin to occur at the 60th percentile in August and September. The shortages become more severe at the 70th percentile; only 50 percent of the reservations can be satisfied at this frequency during August. In other words, in four out of 10 years, only 50 percent or less of the reservations can be satisfied. During September, only 61 percent or less of the reservations would be satisfied. Assuming that an adequate supply of water is needed for irrigation in at least eight out of 10 years (or, severe shortages cannot occur in more than two out of 10 years), it can be seen that problems could arise in August and September.

The values in Tables D-1 through D-5 reflect the assumption that all of the water associated with the irrigation reservations is put to use. If these reservations are not completely developed, shortages would not be as severe. However, results from the main text of this report indicate that little or no water is available for irrigators in excess of the reservations. Therefore, the best way for irrigators to obtain water is from the conservation districts that have reserved the majority of the water associated with the irrigation reservations. These facts tend to suggest that the irrigation reservations will be fully developed.

The figures in Table D-3 indicate that the irrigation reservations on the Clarks Fork of the Yellowstone River would not be satisfied at the 50th percentile in August and the 60th percentile in September. These critical shortages can be attributed to two facts. First, the instream flow reservation for these months at this location is at a higher percentile (70th) than it is at the other locations in the basin above Billings. Also, water in the Clarks Fork is highly appropriated. A substantial number of water use permits for irrigation have been granted. These permits have senior rights to the irrigation reservations. Because of this, irrigators obtaining reserved water from the conservation districts generally may be able to divert water only during periods of high spring flows.

The instream flow reservations at Billings are at a lower percentile flow (higher relative flow rate), except for the Clarks Fork, than the other upstream locations for the irrigation months. Because of this, the Billings instream flow requirements control the amount of water available for irrigation reservations at all upstream locations. For example, the instream reservation at Livingston during August is set at the 95th percentile flow (water in excess of the reservation is available in 9.5 years out of 10, on the average). The August instream reservation at Billings is at the 83rd percentile flow (water in excess of the reservation is available in 8.3 years out of 10). Thus, there

will be times when water in excess of the instream reservation at Livingston is available but can't be used to satisfy irrigation reservations because of an instream flow shortage at Billings. Diverting water at Livingston would increase the water shortage at Billings. The amount of water available for all irrigation reservations above Billings (Table D-5) is, therefore, limited by the instream flow reservations at Billings.

Such logic also indicates that future appropriations of irrigation water (not associated with the irrigation reservations) on the smaller tributaries above Billings will be controlled by the Billings instream flow reservation. As a result, shortages associated with future irrigation appropriations from these smaller tributaries would be similar to those shown in Table D-5. Also, many of the smaller tributaries have their own instream flow requirements that put additional restraints on the future appropriation of water for irrigation. One possible solution for some of these tributaries would be to divert available water from high spring flows into offstream storage reservoirs for later use.

Downstream from Billings, where the irrigation reservations are senior to the instream flow reservation, a shortage was calculated for only one month during the 37-year period of record. The major impacts on the amount of water available to satisfy the irrigation of reservations in this portion of the basin will be future depletions by Wyoming and the Indian tribes. This study strongly suggests that these depletions will not significantly affect the irrigation reservations.

When comparing the amount of water available for satisfying irrigation reservations with the instream flow reservations, the fact that the instream reservations were based on historical flows rather than level of development flows must be considered. Because water use generally has increased over the years, we can assume that water depletions were less during the period represented by the historical flow figures than they were at the time the instream flow reservations were granted (1978). Thus, since the instream flow percentile values were developed from historical flow data, we also can assume that the amount of water available to satisfy irrigation reservations is actually somewhat less than indicated in Tables D-1 through D-5. For example, the instream reservation at Billings for August is set at the 83rd percentile flow, which indicates that water in excess of this reservation would be available for irrigation in 8.3 years out of 10, on the average. Because this percentile value may not accurately represent current water use conditions, the actual availability of excess water for irrigation could be less.

Another fact that must be considered is that the instream flow percentiles represent the frequency at which <u>some</u> water becomes available for the irrigation reservations. The frequency at which <u>all</u> of the water requested for the irrigation reservations becomes available will undoubtedly be less.

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